EFFECT OF FERTILIZER, MANURE AND IRRIGATION ON THE NUTRIENT AVAILABILITY IN SOIL AND YIELD OF BORO RICE

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CERTIFICATE

This is to certify that thesis entitled, **"EFFECT OF FERTILIZER, MANURE AND IRRIGATION ON THE NUTRIENT AVAILABILITY IN SOIL AND YIELD OF BORO RICE"** submitted to the Faculty of Agriculture, Sher-e-Bangla Agricultural University, Dhaka, in partial fulfillment of the requirements for the degree of **MASTER OF SCIENCE IN SOIL SCIENCE,** embodies the result of a piece of *bonafide* research work carried out by **Md. Masfiqur Rahman, Registration No. 06-01958** under my supervision and guidance. No part of the thesis has been submitted for any other degree or diploma.

I further certify that such help or source of information, as has been availed of during the course of this investigation has duly been acknowledged.

Dated:
Dhaka, Bangladesh

(Dr. Md. Asaduzzaman Khan)
Professor
Supervisor

DEDICATED TO

MY

BELOVED PARENTS

who laid the foundation of my success

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ABSTRACT

The experiment was conducted in the farm of Sher-e-Bangla Agricultural University, Dhaka, Bangladesh during the period from December 2012 to July 2012 to study the effect of various organic manures and inorganic fertilizers with different water management on the growth and yield of Boro rice. BRRI dhan29 was used as the test crop in this experiment. The experiment consists of 2 factors i.e. Irrigation and fertilizer plus manure. Two levels of irrigations (I_1= Continuous flooding and I_2= Saturated Condition) were used with 8 levels of fertilizer plus manure, as T_0: Control, T_1: 100% ($N_{120}P_{25}K_{60}S_{20}Zn_2$) Recommended dose of Fertilizer, T_2: 50% NPKSZn + 5 ton cow-dung ha^{-1}, T_3: 70% NPKSZn + 3 ton cow-dung ha^{-1}, T_4: 50% NPKSZn + 5 ton compost ha^{-1}, T_5: 70% NPKSZn + 3 ton compost ha^{-1}, T_6: 50% NPKSZn + 3.5 ton poultry manure ha^{-1} and T_7: 70% NPKSZn + 2.1 ton poultry manure ha^{-1}, with 16 treatment combinations and 3 replications. At the harvest, the yield parameters and yields were recorded; the irrigation had no significant single effect on the yield and yield parameters but grain and straw yields were found in continuous flooded condition. The yield parameters and yields were significantly affected by fertilizer and manure. The highest grain yield (7.40 ton/ha) was found from T_7 (70% NPKSZn + 2.1 ton poultry manure ha^{-1}) treatment which was closely similar to T_6 (50% NPKSZn + 3.5 ton poultry manure ha^{-1}) treatment and lowest yield was obtained from T_0 treatment. The higher grain yields were found by the application of organic plus inorganic fertilizers compared to the use of chemical fertilizer alone. The yield parameters were not significantly influenced by combined application of irrigation and fertilizer and the highest grain yields (7.51 ton/ha) were recorded from I_1T_1 (Continuous flooding + 100% (Recommended dose of Fertilizer) which was closely similar with the yield of I_1T_7 (Continuous flooding + 70% NPKSZn + 2.1 ton poultry manure ha^{-1}) and lowest (3.69 ton/ha) from I_2T_0 (Saturated Condition + control treatment) treatment combination. The pore-water samples were collected and analyzed during rice growing period. The higher concentrations of N, P and K were found in the pore water of T_6 (50% NPKSZn + 3.5 ton poultry manure ha^{-1}) and T_7 (70% NPKSZn + 2.1 ton poultry manure ha^{-1}) treatments where higher yield were obtained. The higher levels of pore-water K concentrations were found in the continuous flooded irrigation (I_1) treatment. The Boro rice grain and straw nutrient concentrations were significantly affected by the application of fertilizer and manure. The higher N, P, K & S concentrations and uptake were observed in the treatments where fertilizer plus manure were applied. The highest concentrations of grain N (1.31%), P (0.272%), K (0.195%) and S (0.091%) were recorded from T_5, T_3, T_7 and T_2 treatment respectively and lowest from T_0 (Control) treatment.

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CHAPTER I

INTRODUCTION

Rice (*Oryza sativa*) is one of the major crops of the world. Rice is a semi aquatic annual grass plant and is the most important cereal crop in the developing world. Rice is the major staple food of nearly half of the world's population, and is particularly important in Asia, where approximately 90% of world's rice is produced and consumed. It is estimated that by the year 2025, the world's farmers should be producing about 60% more rice than at present to meet the food demands of the expected world population at that time. Global rice production has trippled in the last five decades from 150 million tons in 1960 to 450 million tons in 2011, due to the rice Green Revolution in Asia. Since the introduction of high yielding semi-dwarf varieties in 1960s by the International Rice Research Institute (IRRI) more than 1000 modern rice varieties have been released to farmers in many Asian countries, resulting in a rapid increase in rice yields and global rice production. Global production dropped sharply at the beginning of the 21st Century, from 410 million tons in 2000 to 378 million tons in 2003 because of severe droughts in parts of Asia, but has recovered by growing 50 million tons between 2005 and 2011 (Rejesus *et al*., 2012). A study showed that most Asian countries won't be able to feed their projected population without irreversibly degrading their land resources, even with high levels of management inputs (Beinroth *et al*., 2001).

The depleted soil fertility is a major constraint to higher crop production in Bangladesh. The increasing land use intensity has resulted in a great exhaustion of nutrients in soils. Rice-rice cropping system is the most important cropping system in Bangladesh. Continuous cultivation of this highly exhaustive cropping sequence in most of the irrigated fertile lands has resulted in the decline of soil physico-chemical condition in general and particularly soil organic matter (SOM) content. Organic matter decomposition, nutrient mineralization, leaching and efficiency of fertilizer and manures in rice field are greatly affected by the soil moisture level. The bioavailability, uptake of nutrients in soil is dependent on soil moisture and the source of nutrient in soil. Pore-water nutrient is considered to be the pool of nutrient that is most readily available for plant uptake. This research work focuses on better understanding of the solubility of N, P, K and S in pore water and its accumulation in rice. It is necessary to place greater emphasis on strategic research to increase the efficiency of applied nutrients through integration with organic manures with different moisture level.

Rice is intensively cultivated in Bangladesh which covered about 80% of the total cultivable land. But the population density is higher that can't provide them their whole requirements. The main thing is that in Bangladesh the yield of rice is low compare to the other rice growing countries like Japan, South Korea where the average yield is 6.22 and 7.00 ton per hectare chronologically (Islam *et al*., 2013) and the demand is increasing day by day in Bangladesh. Statistically total area under Boro crop has been estimated at 47.70 lac hectares in 2010-11, 48.10 lac hectares in 2011-12, and 47.60 lac hectares in 2012-13. So compared to 2010-11 and 2011-12, the harvested area has increased by 0.83%. But compared to 2011-12 and 2012-13, the harvested area has decreased by 1.04%. (Hossain, 2013) (Source: Bangladesh Bureau of Statistics).

Department of Agricultural Extension has estimated that about 19,685,000 tons of Boro rice was produced in the country during the current 2013-14 season, apparently crossing the official production target. A dry weather condition and lack of natural calamities favored the farmers to get a good harvest of boro paddy, despite the growers suffered a severe shortage of labours.

According to DAE field service wing, over 99 percent of boro paddy at the national level has already been harvested by the farmers with good production of the crop. The government had set a target of boro cultivation acreage at 47.80 lakh hectares of land with production target of 18,916,000 tons for 2013-14 boro season. The growers have actually cultivated boro paddy on some 48.03 lac hectares during the current 2013-14 crop year, with extra 23,000 hectares of land under boro cultivation, (Source: DAE field service wing director Md. Abdul Mannan). He told in the daily newspaper New Age on 10 June 2014, Tuesday that the DAE has estimated the "possible total production of boro" through using sample crop cutting method across the country. According to Bangladesh Bureau of Statistics, 18,778,154 tons of boro rice was produced during the last financial year 2012-13. Meanwhile, DAE field level officials informed that production of high yield varieties and hybrid rice was found better during this year. A super hybrid rice variety SL-8H, which was newly introduced in Bangladesh, grew the highest yield rate at 10 tons per hectare during the current boro season. The DAE has recently estimated the highest yields of SL-8H boro rice at crop cutting programme in Noakhali and Gopalganj districts (Source: DAE field service wing director Md. Abdul Mannan).

For that reason scientists are trying to improve the production systems with the help of combination of organic and inorganic sources of nutrients. The improvement of soil physico-chemical properties by using both chemical and organic fertilizers are supply for essential plant nutrient for higher yield. The application of different levels of irrigation in boro rice affect the yield, nutrient accumulation and boro rice quality. More nutrients are leached out from soil when higher levels of irrigation water are added during boro rice growing period. Moisture levels affect the organic matter accumulation and mineralization. Yang *et al.* (2004) reported that application of chemical fertilizers with farmyard manure or wheat or rice straw in alternate wetting and drying condition increased N, P, & K uptake by rice plants.

Organic manure can supply a good amount of plant nutrients thus can contribute to crop yields. Thus, it is necessary to use fertilizer and manure in an integrated way in order to obtain sustainable crop yield without affecting soil fertility. The integrated approach by using the organic and inorganic sources of nutrients helps to improve the efficiency of nutrients. Mineralization and immobilization are biochemical in nature and are mediated through the activities of microorganisms. The rate and extent of mineralization determines crop availability of nutrients. The transformation of N, P and S in soil depends on the quality and quantity of organic matter as well as soil fertility and microbial activity.

Considering the present situation the present study was undertaken to: develop a suitable integrated dose of inorganic fertilizers combined with different manures for Boro rice; evaluate the effects of inorganic and organic fertilizer with different water management on the yield, yield components and nutrient concentration of Boro rice; and investigate the improvement of soil fertility due to the use of organic manure in combination with chemical fertilizers.

This detailed study was under taken with the following objectives:

i. To develop a suitable integrated dose of inorganic fertilizers combined with different manures for Boro rice.
ii. To evaluate the effects of combined application of inorganic and organic fertilizer with different water management on the yield, yield components and quality of Boro rice.
iii. To maintain the soil health by adopting Integrated Nutrient Management system in rice cultivation.
iv. To investigate, the improvement of soil fertility due to the use of organic manure in combination with chemical fertilizers.
v. To investigate the availability of N, P, K and S in pore water of cropped and un-cropped soil with different fertilizer application.

CHAPTER II

REVIEW OF LITERATURE

Soil organic manure and inorganic fertilizer is the essential factor for sustainable soil fertility and crop productivity because is the store house of plant nutrients. Sole and combined use of cow-dung, poultry manure, compost, and inorganic fertilizer acts as a source of essential plant nutrients. Experimental evidences in the use of cow-dung, poultry manure, compost, and nitrogen, phosphorus, potassium and sulphur showed an intimate effect on the yield and yield attributes of rice. Yield and yield contributing characters of rice are considerably influenced by different doses of NPKS fertilizer and cow-dung, poultry manure & compost manure and their combined application. On the other hand Irrigation also an important factor for the sustainable soil fertility and crop productivity. Some literature related to the "**EFFECT OF FERTILIZER, MANURE AND IRRIGATION ON THE NUTRIENT AVAILABILITY IN SOIL AND YIELD OF BORO RICE**" are reviewed below-

2.1 Effect of chemical fertilizer on the growth and yield of rice

Jeffery *et al.* (2011) Increased attention is being given to the improvement of such soils, since they are potentially productive and require less investment, effort, and time for restoring their productivity than is required for the reclamation of new land.

Anwar *et al.* (2005) Soil fertility management through the application of organic matter and other soil amendments to supply at least a part of plants' nutrient requirement, rather than rely entirely on inorganic fertilizer, and to improve the soil fertility level is imperative for making such soils productive.

Satyanarayana *et al.* (2002) Significant influence of different inorganic fertilizer levels on grain and straw yield, tiller numbers, filled grains per panicle and 1000-grain weight of rice. Application of 120 : 60 : 45 kg N: P_2O_5 : K_2O ha^{-1} produced significantly greater grain yield (3.63 t ha^{-1}) as compared to that obtained with lower fertilizer levels of N: P_2O_5 : K_2O ha^{-1} (3.17 t ha^{-1}).

Behera *et al.* (2009) Application of higher fertilizer level of 160 : 80 : 60 N: P_2O_5 : K_2O ha^{-1} produced grain yield of 3.76 t ha^{-1}, which was statistically similar to that obtained with application of 120 : 60 : 45 kg N: P_2O_5 : K_2O ha^{-1}. Similar effects were also observed for straw yield, number of tillers, filled grains per panicle and 1000-grain weight. These effects were due mainly to low available N and P in the soil.

Ndaeyo *et al.* (2008) conducted an experiment in Nigeria with five rice varieties (WAB340- 8-8-2HI, WAB881-10-37-18-8-2-HI, WAB99-1-1, WAB224-8-HB, WAB189-B-B-B-8-HB) and four rates of NPK (15:15:15) fertilizer (0, 200, 400 and 600kg/ha). The results showed that

600kg/ha NPK (15:15:15) fertilizer rate significantly ($P < 0.05$) increased plant height, number of leaves and tillers per plant in both years. The 400kg/ha rate increased the number of panicles per plant, length of central panicle per plant and the overall grain yields, straw yield over other rates by 4-32% and 2-21% in 2005 and 2006, respectively.

Amim *et al.* (2004) conducted an experiment to evaluate the effect of increased plant density and fertilizer dose on yield of rice variety IR-6. He found that increased fertilizer dose of NPK increase plant height.

2.2 Combined effect of chemical fertilizer and manure on the growth and yield of rice

2.2.1 Combined effect of chemical fertilizer and poultry manure, cowdung manure on the growth and yield of rice

Buri *et al*. (2006) in an experiment with poultry manure, cattle manure, and rice husks, applied solely or in combination with mineral fertilizer (using urea or sulphate of ammonia as N source), found that a combination of a half rate of organic amendments and a half rate of mineral fertilizer significantly contributed to the growth and yield of rice.

Nyalemegbe *et al*. (2010) found that combining 10 t ha^{-1} of cow dung with 45 kg N ha^{-1} urea, or 10 t ha^{-1} poultry manure with 60 kg N ha-1, gave yields comparable to those under high levels of nitrogen application (i.e., 90 and 120 kg N ha^{-1}) applied solely.

Nyalemegbe *et al*. (2009) found that rice straw surpassed poultry manure and cow-dung in the Vertisols of the Accra Plains of Ghana.

2.2.2 Combined effect of chemical fertilizer and compost on the growth and yield of rice

Najafi *et. al.*, (2013) Combination with 120 : 60 : 45 kg N: P_2O_5 : K_2O ha^{-1} produced an optimum grain yield when compared to other treatment combinations. Furthermore, the positive effects of farmyard manure were not enhanced with increased rate of inorganic fertilizer application. This is in agreement with other studies where combined application of organic and inorganic fertilizer increased productivity of rice.

Nayak *et. al.,* (2007) reported that application of compost and inorganic fertilizer increased microbial growth in soil, vegetative growth and maximum tillering of rice.

Jarin *et. al.,* (2013) conducted an experiment to investigate the effect of manure and municipal compost and their enrichment with chemical fertilizers on growth and yield of rice. Results showed that compost alone did not increase grain yield. However, when enriched with different levels of chemical fertilizer the highest amount of grain yield was produced. The yield was comparable to the yield obtained from 40 t/ha of compost. This indicated that compost might be an appropriate substitute for manure and half of chemical fertilizer needed for soil.

Omar *et al*. (2008) found the effect of compost of the some plant residues i.e. rice straw and cotton stalk on some physical and chemical properties of the sandy soil. Application of cotton stalks or rice straw composts significantly improved the physical properties of the tasted soil, i.e., bulk density, hydraulic conductivity and moisture content namely field capacity, wilting point and available water, concerning the effect of compost application on the availability of N, P and K in the cultivated soil, rice straw was better than cotton stalks.

2.2.3 Combined effect of chemical fertilizer and FYM on the growth and yield of rice

Sharma *et. al*., (2008) Using 10 ton ha-1 FYM with 75% of the recommended chemical nitrogen performed better in terms of plant growth, grain yield and yield components score.

Man *et al*. (2007) stated that chemical fertilizer inputs can be reduced by 20 to 60% from the present recommended application rate by using rice straw manure (6 t ha-1) without decreasing rice yield and yield components, while keeping high soil fertility level and high availability of nutrients.

Satyanarayana *et al.* (2002) Data on the uptake studies showed that application of farmyard manure increased the uptake of N, P, and K by 20, 12, and 9%, respectively. There were significant interactions between organic manure and fertilizer treatment. Maximum uptake of N, P, and K was observed at a fertilizer level of 120 : 60 : 45 kg N: P_2O_5 : K_2O ha^{-1} in combination with application of farm yard manure.

Akter *et al.* (2011) The increase in P and K in farmyard manure application treatment could be attributed to enhanced availability of these nutrients due to improved soil structure and increased microbial activity. Research has shown that combined application of farmyard manure and green manure could meet all the nitrogen requirement (150 kg fertilizer N ha^{-1}) of the high yielding varieties and yielded better than the application of inorganic fertilizer alone.

Berry *et al.* (2002) Long-term effects of integrated nutrient management on productivity of rice-rice cropping system in both rainy and post-rainy seasons showed that the use of inorganic fertilizer (50%) and farmyard manure or green manure (50%) produced better yields than those obtained by application of 100% of recommended inorganic N.

Satyanarayana *et al.* (2002) In general the beneficial effects of farmyard manure on yield, yield attributes, and nutrient uptake was less noticeable with increasing levels of inorganic fertilizer. An optimum yield of rice was obtained by application of 120 : 60 : 45 kg N:P_2O_5 : K_2O ha^{-1} in combination with farmyard manure. The higher yield obtained with integrated use of farmyard manure and inorganic fertilizers were attributed to increased nutrient availability and uptake, resulting in greater number of tillers, filled grains per panicles and 1000-grain weight.

2.3 Effect of irrigation on growth and yield of rice

Thakur *et al*. (2011) observed that system of rice intensification practices with alternate wet and drying improve rice plants morphology and it benefits physiological processes that results in higher grain yield water productivity.

Zhao *et al*. (2011) found that total water use efficiency and irrigation water use efficiency was increased with system of rice intensification (SRI) by 54.2 and 90% respectively. Thus, SRI offered significantly greater water saving while at the same time producing more grain yield of rice in these trials 11.5% more compared to traditional flooding.

Lin *et al*. (2011) reported that intermittent water application with SRI management, grain yield increased by 10.5 and 11.3%, compared to standard irrigation practice (continuous flooding).

They also reported that intermittent irrigation with organic material application improved the function of rhizosphere and increased yield of rice.

Aulakh (1996) In soils with light texture (sandy soil), soil doesn’t have high water holding capacity, thus in such a situation irrigation periods may be constant or its frequency increases, however, in deficit irrigation the water amount reduces compared to normal irrigation in each irrigation.

3.0 Changes in soil fertility and properties due to integrated use of chemical fertilizers and manure

Zayed *et al*., (2013) Sole application of nitrogen at 165 kg N ha^{-1} significantly increased the number of days to heading compared to the control and bio-fertilizer treatments. However, during the second year, the difference was no longer significant in comparison with the organic fertilizer treatments.

Ilma *et al*., (2012) conducted a field experiment to improve soil physical and chemical properties in organic agriculture. The incorporation of green manure crops, the application of compost and other organic fertilizers and amendments, combined with suitable soil cultivation practices are part of the practices, aimed at achieving this goal. The role of soil microorganisms in achieving optimal nutritional regime in organic agriculture was reviewed. Soil microbial flora control for the enhancement of the domination of the beneficial and effective microorganisms could prove to be a means for the improvement and maintenance of optimal physical and chemical soil properties in organic agriculture.

Golabi *et al.* (2007) observed that one of the major problems in agricultural soils is their low organic matter content, which results from rapid decomposition due to the hot and humid environment. Composted organic material is frequently applied on agricultural fields as an amendment to provide nutrients and also to increase the organic matter content and to improve the physical and chemical properties of soils.

Altieri *et al.* (2003) With the treatment and the other organic fertilizer treatments, it was observed that during the second season, soil organic matter, as well as soil nitrogen and phosphorus content, significantly increased over those values from inorganic fertilizer application.

Residual effects of organic fertilizer application were manifested with an increase in soil nutrient availability during the second season. This led to better plant growth, higher dry matter production, improved LAI, and higher plant tissue content of nitrogen and phosphorus. Similar data have been reported by Zayed *et al*. (2007, 2008).

Zayed *et al*. (2007, 2008) mention that organic fertilizer treatments reduced soil pH levels and more in the second season than in the first. Application of organic fertilizers, especially 5 t ha-1 RSC + 110 kg N ha-1, and 7 t FYM + 5 t RSC + *Azo*., significantly increased soil potassium, zinc and ferrous iron content in both seasons, with the second-season results being even higher.

Palm *et al*. (1997) found the positive impact of organic fertilizers on soil fertility improvement might be due to the following relationships. First, decomposition and mineralization of nutrients present in the organic material. Secondly, release of some organic acids as a result of organic decomposition which reduces the soil pH, while improving nutrient availability.

CHAPTER III

MATERIALS AND METHODS

The experiment was conducted in the Farm of Sher-e-Bangla Agricultural University, Dhaka, Bangladesh during the period from December 2012 to July 2013 to study the effect of various organic manure and inorganic fertilizer with different water management on the growth, yield of Boro rice and nutrient availability in soil during rice growing period. This chapter includes materials and methods that were used in conducting the experiment. The details are presented below under the following headings:

3.1 Experimental Site and Soil

The experiment was conducted in typical rice growing silt loam soil at the Sher-e-Bangla Agricultural University Farm, Dhaka during the *Boro* season of 2012-13. The morphological, physical and chemical characteristics of the soil are shown in the Table 3.1 and 3.2.

Table 3.1: Morphological Characteristics of the Experimental Field

Morphology	Characteristics
Location	SAU Farm, Dhaka
Agro-ecological zone	Madhupur Tract (AEZ- 28)
General Soil Type	Deep Red Brown Terrace Soil
Parent material	Madhupur clay
Topography	Fairly level
Drainage	Well drained
Flood level	Above flood level

(FAO and UNDP, 1988)

3.2 Climate

The climate of the experimental area is characterized by high temperature, high humidity and medium rainfall with occasional gusty winds during the *kharif* season (March-September) and a scanty rainfall associated with moderately low temperature in the R*abi* season (October-March). The weather information regarding temperature, rainfall, relative humidity and sunshine hours prevailed at the experimental site during the cropping season January 2013 has been presented in Appendix I.

Table 3.2: Initial Physical and Chemical Characteristics of the Soil

Characteristics		**Value**
Mechanical fractions:	% Sand (2.0-0.02 mm)	22.26
	% Silt (0.02-0.002 mm)	56.72
	% Clay (<0.002 mm)	20.75
Textural class		Silt Loam
pH (1: 2.5 soil- water)		5.9
Organic Matter (%)		1.09
Total N (%)		0.06
Available K (ppm)		15.63
Available P (ppm)		10.99
Available S (ppm)		6.07

3.3 Planting Material

BRRI dhan 29 was used as the test crop in this experiment. This variety was developed at the Bangladesh Rice Research Institute from the cross between BG 90-2 and BR51-46-5 in 1994. It is recommended for *Boro* season. Average plant height of the variety is 90-95 cm at the ripening stage. The grains are medium fine and white. It requires about 155-160 days completing its life cycle with an average grain yield of 5.0-5.5 ton per ha (BRRI, 2004).

3.4 Land Preparation

The land was first opened by a tractor and prepared thoroughly by ploughing and cross ploughing with a power tiller followed by country plough. Laddering helped breaking the clods and leveling the land followed every ploughing. Before transplanting each unit of plot was cleaned by removing the weeds, stubbles and crop residues. Finally each plot was prepared by puddling.

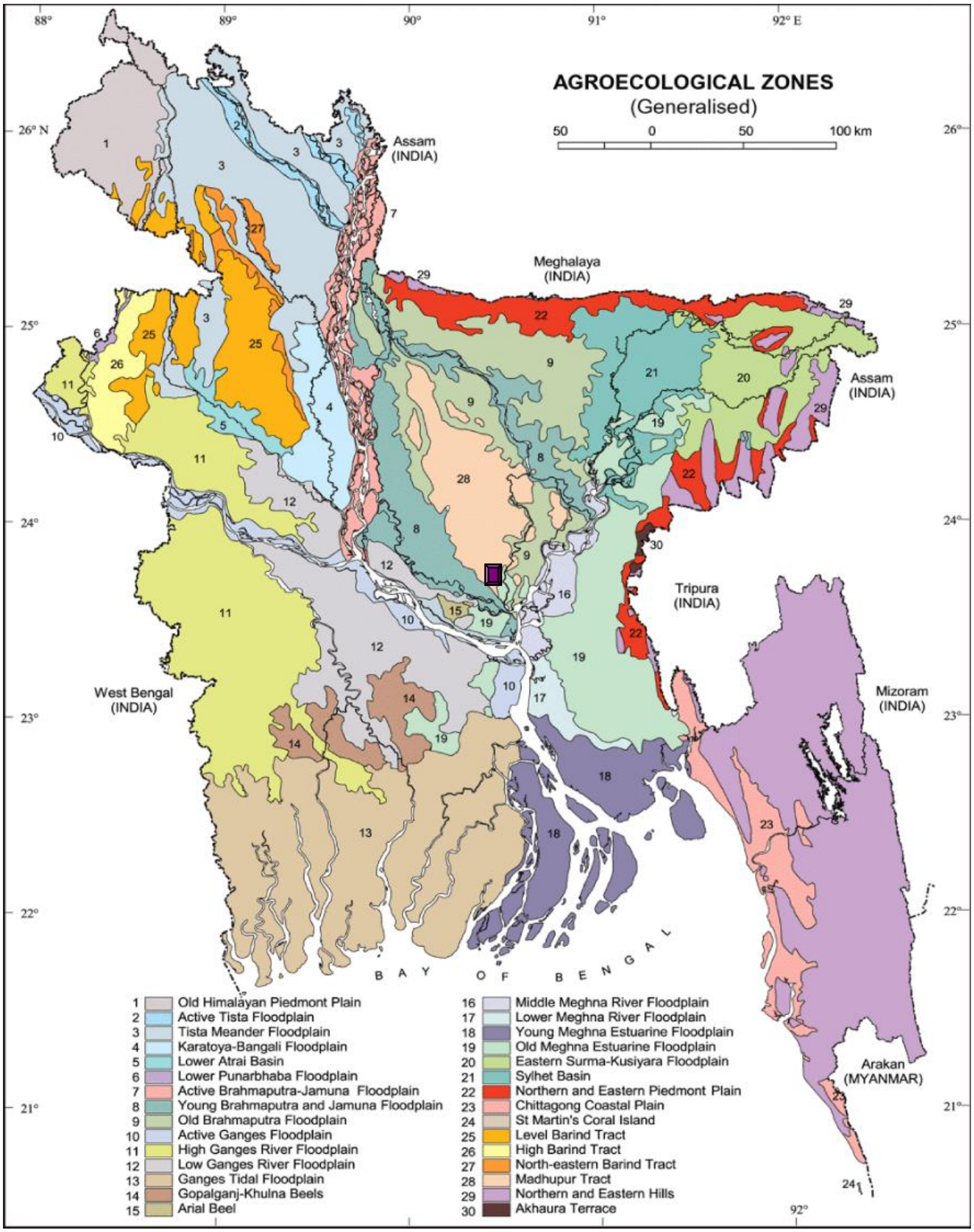


Figure 1: Map showing the experimental sites under study

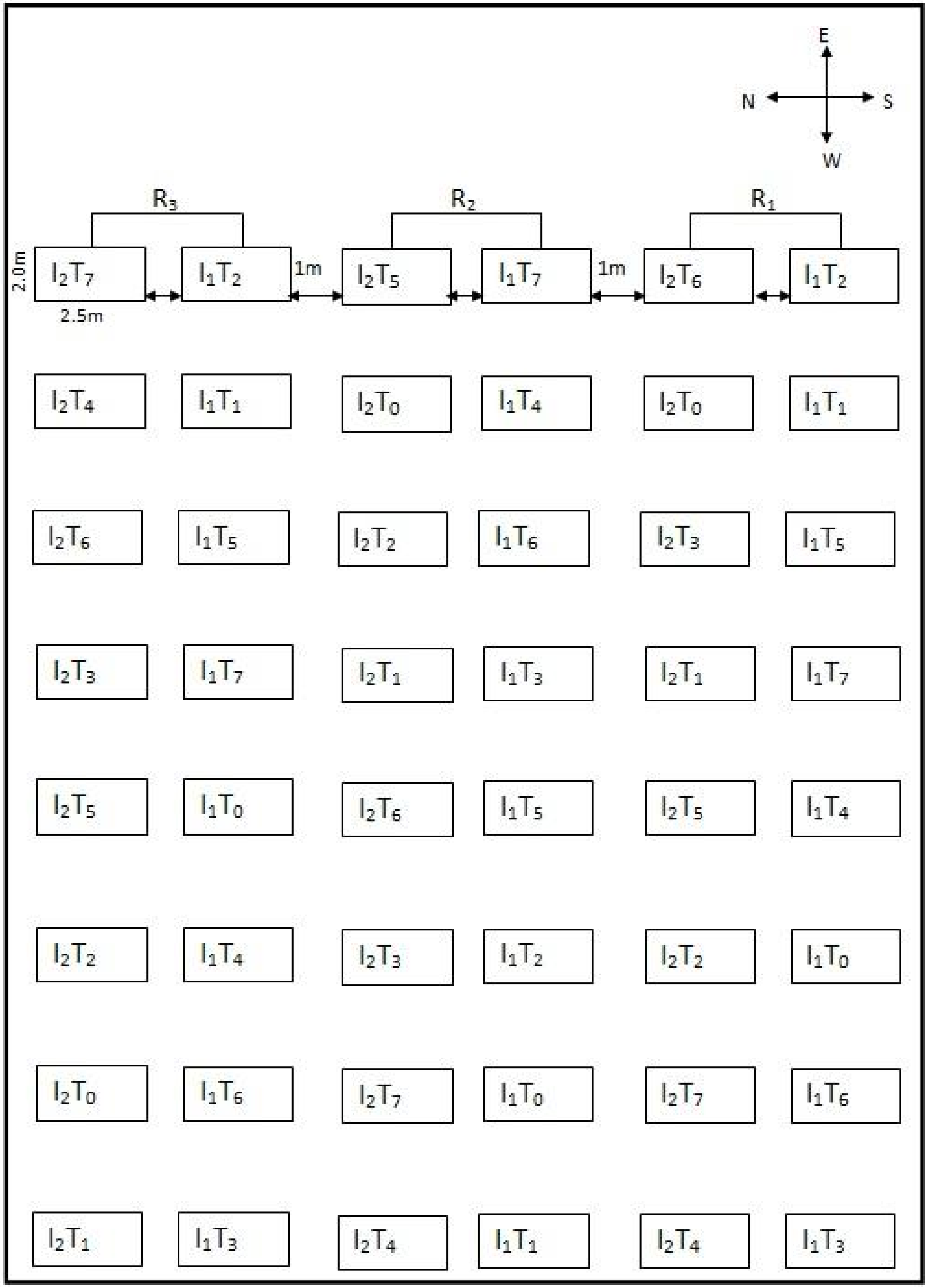


Figure 2: Layout of the experimental Plot of Boro Rice

3.5 Experimental Design and Layout

The experiment was laid out in a split plot design (SPD) with three replications. The layout was made distributing two irrigations (continuous flooding and saturated condition) to the main plots and fertilizer plus manure treatments to the sub plots. The total number of plots was 48; measuring 2.5 m × 2 m and ailes separated plots from each other. The distance maintained between two main plots and two sub plots were 1.0 m and 0.5 m respectively. In each sub-plot a 30 cm diameter and 40 cm long PVC pipe was installed in the centre of the Sub-Plot.

3.6 Initial Soil Sampling

Before land preparation, initial soil samples at 0-15 cm depth were collected from different spots of the experimental field. The composite soil sample were air-dried, crushed and passed through a 2 mm (8 meshes) sieve. After sieving, the soil samples were kept in a plastic container for physical and chemical analysis of the soil.

3.7 Treatments

The experiment consists of 2 factors i.e. irrigation and fertilizer plus manure. Details of factors and their combinations are presented below:

Factor A: 2 Level of Irrigation in the Main Plot

I_1= Continuous flooding

I_2= Saturated condition

Factor B: 8 Fertilizer, Manure Treatment in the Sub Plot

T_0: Control

T_1: 100% ($N_{120}P_{25}K_{60}S_{20}Zn_2$) Recommended dose of Fertilizer

T_2: 50% NPKSZn + 5 ton cowdung ha^{-1}

T_3: 70% NPKSZn + 3 ton cowdung ha^{-1}

T_4: 50% NPKSZn + 5 ton compost ha^{-1}

T_5: 70% NPKSZn + 3 ton compost ha^{-1}

T_6: 50% NPKSZn + 3.5 ton poultry manure ha^{-1}

T_7: 70% NPKSZn + 2.1 ton poultry manure ha^{-1}

Treatment Combination

I_1T_0 = (Continuous flooding + Control)
I_1T_1 = Continuous flooding + 100% ($N_{120}P_{25}K_{60}S_{20}Zn_2$) (Recommended dose)
I_1T_2 = (Continuous flooding + 50% NPKSZn + 5 ton cowdung ha^{-1})
I_1T_3 = (Continuous flooding + 70% NPKSZn + 3 ton cowdung ha^{-1})
I_1T_4 = (Continuous flooding + 50% NPKSZn + 5 ton compost ha^{-1})
I_1T_5 = (Continuous flooding + 70% NPKSZn + 3 ton compost ha^{-1})
I_1T_6 = (Continuous flooding + 50% NPKSZn + 3.5 ton poultry manure ha^{-1})
I_1T_7 = (Continuous flooding + 70% NPKSZn + 2.1 ton poultry manure ha^{-1})
I_2T_0 = (Saturated condition + Control)
I_2T_1 = Saturated condition + 100% ($N_{120}P_{25}K_{60}S_{20}Zn_2$) (Recommended dose)
I_2T_2 = (Saturated condition + 50% NPKSZn + 5 ton cowdung ha^{-1})
I_2T_3 = (Saturated condition + 70% NPKSZn + 3 ton cowdung ha^{-1})
I_2T_4 = (Saturated condition + 50% NPKSZn + 5 ton compost ha^{-1})
I_2T_5 = (Saturated condition + 70% NPKSZn + 3 ton compost ha^{-1})
I_2T_6 = (Saturated condition + 50% NPKSZn + 3.5 ton poultry manure ha^{-1})
I_2T_7 = (Saturated condition + 70% NPKSZn + 2.1 ton poultry manure ha^{-1})

3.8 Fertilizer Application

The amounts of N, P, K, S and Zn fertilizers required per plot were calculated as per the treatments. Full amounts of TSP, MP, Gypsum and Zinc sulphate were applied as basal dose before transplanting of rice seedlings. Urea were applied in 3 equal splits: one third was applied at basal before transplanting, one third at active tillering stage (30 DAT) and the remaining one third was applied at 5 days before panicle initiation stage (55 DAT). Fertilizers were applied into the core and outside the core during final land preparation.

3.9 Organic Manure Incorporation

Three different types of organic manure viz. cow-dung, poultry manure and compost were used. The rates of manure as 5 & 3, 3.5& 2.1 and 5 & 3 ton per ha for cow-dung, poultry manure and compost per plot were calculated as per the treatments, respectively. Cow-dung, compost and poultry manure were applied before four days of final land preparation. Chemical compositions of the manures used have been presented in Table 3.3.

Table 3.3: Chemical Compositions of the Cow-dung, Poultry Manure and Compost (Oven dry basis)

Sources of organic manure	Nutrient content			
	N (%)	P (%)	K (%)	S (%)
Cow-dung	1.46	0.29	0.74	0.24
Poultry manure	2.2	1.99	0.82	0.29
Compost	1.49	0.28	1.60	0.32

3.10 Raising of Seedlings

The seedlings of rice were raised wet-bed methods. Seeds (95% germination) @ 5 kg per ha were soaked and incubated for 48 hour and sown on a well-prepared seedbed. During seedling growing, no fertilizers were used. Proper water and pest management practices were followed whenever required.

3.11 Transplanting

Forty days old seedlings of BRRI dhan29 were carefully uprooted from the seedling nursery and transplanted in 18 January, 2013 in well puddle plot. Two seedlings per hill were used following a spacing of 20 cm × 15 cm. After one week of transplanting all plots were checked for any missing hill, which was filled up with extra seedlings whenever required.

3.12 Intercultural Operations

Intercultural operations were done to ensure normal growth of the crop. Plant protection measures were followed as and when necessary. The following intercultural operations were done.

3.12.1 Irrigation

Treatment wise irrigation levels were maintained in different plots and necessary irrigations were provided to the plots as and when required during the growing period of rice crop.

3.12.2 Pore Water Collection

Pore-water samples were collected from inner and outside the cores during Boro rice growing period by using rhizon sampler (Rhizon MOM 10 cm length, 2.5 mm OD, Rhizosphere Research Products, Wageningen, and The Netherlands) during the different dates of rice growing periods.

The pore-water samples were filtered through Whatman no. 42 filter paper and analyzed for N, P, K and S contents by standard method (Plate 1&2).

Plate 1: Rhizon Sampler

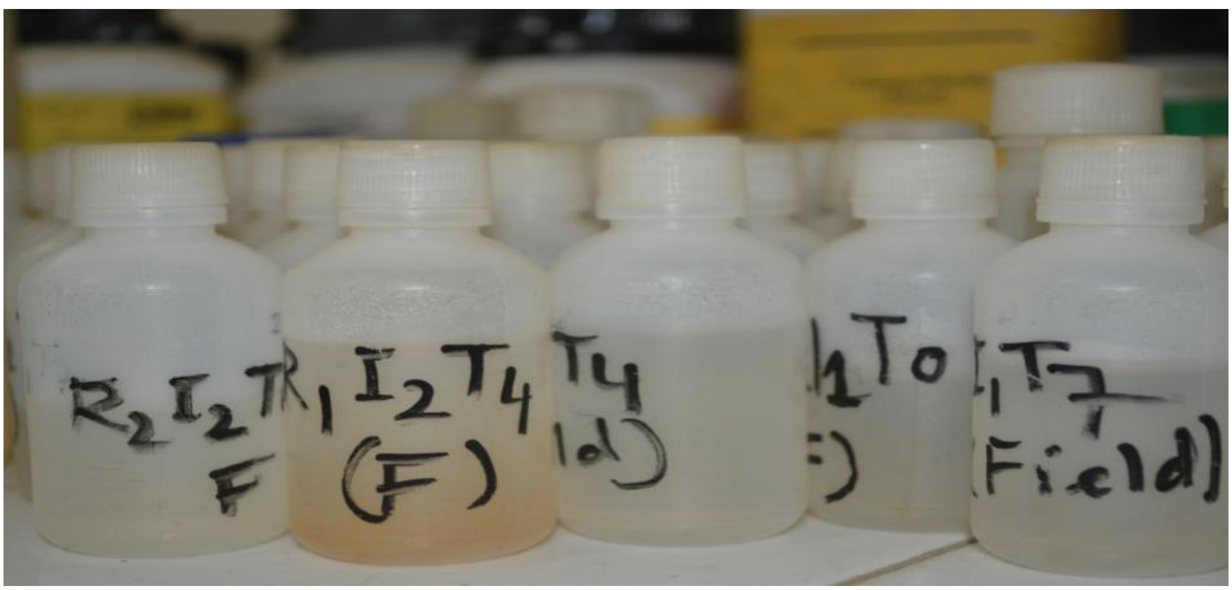


Plate 2: Pore Water Samples

3.12.3 Weeding

The plots were infested with some common weeds, which were removed by uprooting them from the field three times during the period of the cropping season.

3.12.4 Insect and Pest Control

There was no infestation of diseases in the field but leaf roller (*Chaphalocrosismedinalis*, Pyralidae, Lepidoptera) was observed in the field and used Malathion @ 1.12 Liter per ha.

3.13 Crop Harvest

The crop was harvested at full maturity when 80-90% of the grains were turned into straw colored on June, 2013. The crop was cut at the ground level and plot wise crop was bundled separately and brought to the threshing floor. Ten hills of rice plant were selected randomly from the plants for measuring yield contributing characters.

3.14 Yield Components:

3.14.1 Total Number of Effective Tiller per Hill

The total number of effective tiller per hill was counted as the number of panicle bearing hill per plant. Data on effective tiller per hill were counted from 10 selected hills and average value was recorded.

3.14.2 Total Number of Non Effective Tiller per Hill

The total number of non effective tiller per hill was counted as the number of non-panicle bearing plant per hill. Data on non effective tiller per hill were counted from 10 randomly selected hills and average value was recorded.

3.14.3 Plant Height

The height of plant was recorded in centimeter (cm) at harvesting stage. Data were recorded as the average of 10 plants selected at random from the inner rows of each plot. The height was measured from the ground level to the tip of the panicle.

3.14.4 Length of Panicle (cm)

The length of panicle was measured with a meter scale from 10 selected plants and the average value was recorded as per plant.

3.14.5 Number of Unfilled and Filled Grain per Panicle

The total numbers of unfilled grains were calculated from selected 10 plants of a plot on the basis of not grain in the spikelet and then average numbers of unfilled grain per panicle was recorded. Similarly filled grains per panicle were counted.

3.14.6 Weight of 1000 Seeds (gram)

One thousand seeds were counted randomly from the total cleaned harvested seeds and then weighed in grams and recorded.

3.14.7 Straw Weight (kg)

Straw obtained from each unit plot were sun-dried and weighed carefully. The dry weight of straw of the respective unit plot yield was converted to ton per ha.

3.14.8 Grain Yield (kg)

Grains obtained from each unit plot were sun-dried and weighed carefully. The dry weight of grains of the respective unit plot yield was converted to ton per ha.

3.15 Chemical Analysis of Plant Samples:

3.15.1 Collection and Preparation of Plant Samples

Grain and straw samples were collected after threshing for N, P, K and S analyses. The plant samples were dried in an oven at 70 ^{0}C for 72 hours and then ground by a grinding machine (Wiley-mill) to pass through a 20-mesh sieve. The samples were stored in plastic vial for analyses of N, P, K and S. The grain and straw samples were analyzed for determination of N, P, K and S concentrations.

3.15.2 Digestion of Plant Samples with Sulphuric Acid for N Analysis

For the determination of nitrogen an amount of 0.5 g oven dry, ground sample were taken in a micro Kjeldahl flask. 1.1 g catalyst mixture (K_2SO_4: $CuSO_{4.}$ $5H_2O$: Se in the ratio of 100: 10: 1), and 7 ml conc. H_2SO_4 were added. The flasks were heated at 160^{0}C and added 2 ml 30% H_2O_2 then heating was continued at 360 ^{0}C until the digests become clear and colorless. After cooling, the content was taken into a 50 ml volumetric flask and the volume was made up to the mark with de-ionized water. A reagent blank was prepared in a similar manner. Nitrogen in the digest was estimated by distilling the digest with 10 N NaOH followed by titration of the distillate trapped in H_3BO_3 indicator solution with 0.01N H_2SO_4.

3.15.3 Digestion of Plant Samples with Nitric-Perchloric Acid for P, K and S Analysis

A sub sample weighing 0.5 g was transferred into a dry, clean 100 ml digestion vessel. Ten ml of di-acid (HNO_3: $HClO_4$ in the ratio 2:1) mixture was added to the flask. After leaving for a while, the flasks were heated at a temperature slowly raised to 200^0C. Heating were stopped when the dense white fumes of $HClO_4$ occurred. The content of the flask were boiled until they were became clean and colorless. After cooling, the content was taken into a 100 ml volumetric flask and the volume was made up to the mark with de-ionized water. P, K and S were determined from this digest by using different standard methods.

3.15.4 Determination of P, K and S from Plant Samples:

3.15.4.1 Phosphorus

Plant samples (grain and straw) were digested by di-acid (Nitric acid and Perchloric acid) mixture and P content in the digest was measured by blue color development (Olsen *et al.*, 1954). Phosphorus in the digest was determined by using 1 ml for grain sample and 2 ml for straw sample from 100 ml digest by developing blue color with reduction of phosphomolybdate complex and the color intensity were measured colorimetrical at 660 nm wavelength and readings were calibrated with the standard P curve (Page *et al*., 1982).

3.15.4.2 Potassium

Ten milli-liters of digest sample for the grain and five ml for the straw were taken and diluted 50 ml volume to make desired concentration so that the flame photometer reading of samples were measured within the range of standard solutions. The concentrations were measured by using standard curves.

3.15.4.3 Sulphur

Sulphur content was determined from the digest of the plant samples (grain and straw) as described by Page *et al*., 1982. The digested S was determined by developing turbidity by adding acid seed solution (20 ppm S as K_2SO_4 in 6N HCl) and $BaCl_2$ crystals. The intensity of turbidity was measured by spectrophotometer at 420 nm wavelengths (Hunter *et al*., 1984).

3.16 Pore Water Analysis:

Pore water samples were analyzed for both physical and chemical characteristics viz. total N and available P, K, and S contents. The Pore water samples were analyzed by the following standard method as follows:

3.16.1 Total Nitrogen

Total N content of pore water samples were determined followed by the Micro Kjeldahl method. 10 ml pore water was transferred into the distillation flask, Then 10 ml of H_3BO_3 indicator solution was taken into a 250 ml conical flask which is marked to indicate a volume of 50 ml and placed the flask under the condenser outlet of the distillation apparatus so that the delivery end dipped in the acid. Add sufficient amount of 10N-NaOH solutions in the container connecting with distillation apparatus. Water running through the condenser of distillation apparatus was checked. By operating the switch of the distillation apparatus distillate was collected. The conical flask was removed by washing the delivery outlet of the distillation apparatus with distilled water.

Finally the distillates were titrated with standard 0.01 N H_2SO_4 until the color changes from green to pink.

The amount of N in pore water was calculated using the following formula:

$$\% N = (T-B) \times N \times 0.014 \times 100 / S$$

Where,

T = Sample titration (ml) value of standard H_2SO_4

B = Blank titration (ml) value of standard H_2SO_4

N = Strength of H_2SO_4

S = Sample volume in milliliter

3.16.2 Available Phosphorus

Phosphorus in the pore water was determined by developing blue color with reduction of phosphomolybdate complex and the color intensity were measured colorimetrical at 660 nm wavelength and readings were calibrated the standard P curve (Page *et al*. 1982).

3.16.3 Available Potassium

Readily available K was determined in pore water by using flame photometer and calibrated with a standard curve (Page *et al*. 1982).

3.16.4 Available Sulphur

Available S content in pore water was determined by turbidimetrically described by (Page *et al*., 1982). The pore water S was determined by developing turbidity by adding acid seed solution (20 ppm S as K_2SO_4 in 6N HCl) and $BaCl_2$ crystals. The intensity of turbidity was measured by spectrophotometer at 420 nm wavelengths.

3.17 Statistical Analysis

The data obtained for different parameters were statistically analyzed to find out the significant difference of different treatments on yield and yield contributing characters of BRRI dhan 29. The mean values of all the characters were calculated and analysis of variance was performed by the ‘F’ (variance ratio) test and Microsoft Office Excel 2007. The significance of the difference among the treatment means was estimated by the Duncan’s Multiple Range Test (DMRT) at 5% level of probability (Gomez *et. al.,* 1984).

CHAPTER IV

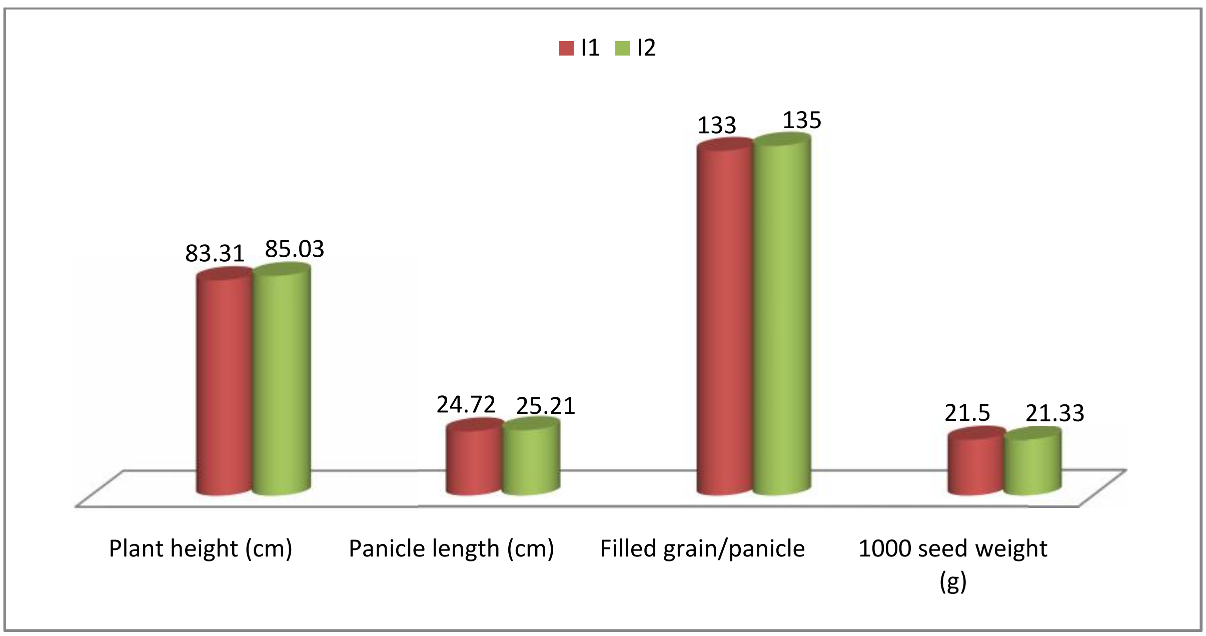
RESULTS AND DISCUSSION

The results of pore-water nutrient availability, different yield attributes, yield and nutrient concentrations in the plant and grains and availability of different nutrients in the soil after harvest of rice are presented in this chapter.

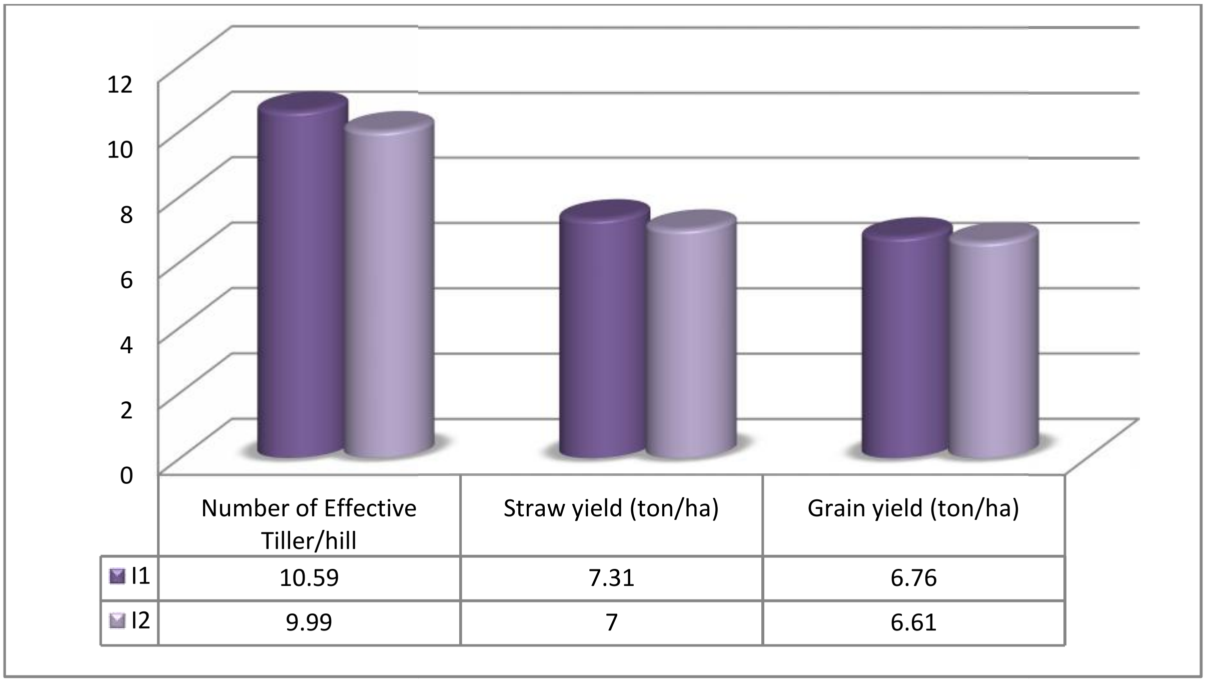
4.1 Effective Tiller

4.1.1 Effect of Irrigation and Fertilizer on the Growth and Yield of Boro Rice

The number of effective tillers hill^{-1}, plant height, panicle length and filled grains per panicle were not significantly affected by irrigation but significantly influenced by fertilizer and manure application. Between the two levels of irrigation, I_1 (Continuous flooding) showed highest number of effective tillers/hill (10.59) and I_2 (Saturated condition) showed lower number of effective tillers/hill (9.99). I_1 (Continuous flooding) showed lower plant height (83.31 cm) and I_2 (Saturated condition) showed higher plant height (85.03 cm). I_1 (Continuous flooding) showed lower panicle length (24.72 cm) and I_2 (Saturated condition) showed higher panicle length (25.21 cm). I_1 (Continuous flooding) showed lower filled grain per panicle (133) and I_2 (Saturated condition) showed higher filled grain per panicle (135). The 1000 grain weight, grain and straw yields were not significantly influenced by irrigation treatments. I_1 (Continuous flooding) showed 1000 seed weight (21.50 g) and I_2 (Saturated condition) showed 1000 seed weight (21.33 g). I_1 (Continuous flooding) showed higher straw yield (7.31ton/ha) and I_2 (Saturated condition) showed lower yield (7.00 ton/ha). I_1 (Continuous flooding) showed higher grain yield (6.76 ton/ha) and I_2 (Saturated condition) showed lower grain yield (6.61 ton/ha) (Figure 3).



(1)



(2)

I_1=Continuous flooded; I_2= Saturated condition

Figure 3 (Both 1&2): Effect of Irrigation on the Growth and Yield Parameter of Boro Rice

4.1.2 Effect of Fertilizer and Manure on the Yield Parameters and Yield of Boro Rice in Different Treatment

Among the different fertilizer treatments, T_5 (70% NPKSZn + 3 ton compost/ha) showed the highest number of effective tillers/hill (11.1) which was statistically similar to all other treatments except T_0 (Table 4.1). The T_7 (70% NPKSZn + 2.1 ton poultry manure/ha) treatment showed the highest plant height (87.8 cm) which was statistically similar to all other treatment except control. Similarly, the highest panicle length was obtained in T_3 treatment and the control (T_0) treatment gave the lowest number of effective tillers/hill, plant height, panicle length and filled grains panicle^{-1}.

The application of fertilizers and manure had a positive effect on the grain and straw yield of boro rice (Table 4.1). Among the different doses of fertilizers, T_7 (70% NPKSZn + 2.1 ton poultry manure/ha) showed the highest grain yield (7.40 t/ha) which was statistically similar to

T_1, T_2, T_3, T_5 & T_6 treatments and the lowest grain yield/plot (3.95 t/ha) was observed with T_0 where no fertilizer was applied. Similarly, the highest straw yield (8.00 t ha^{-1}) was obtained in T_7 (70% NPKS + 2.1 ton poultry manure/ha) treatment which was statistically similar to T_1, T_3. and T_6 treatments respectively and the lowest straw yield was obtained in T_0 treatment.

Table 4.1: Effect of Fertilizer and Manure on the Yield Parameter and Yield of Boro Rice

Treatments	Number of effective tillers/hill	Plant height (cm)	Panicle length (cm)	Number of filled grain/ panicle	Straw yield (ton/ha)	Grain yield (ton/ha)
T_0	8.2b	72.48b	22.38b	103	4.57d	3.95c
T_1	10.0a	85.68a	25.14a	144	7.78ab	7.25a
T_2	10.4a	84.91a	25.01a	142	7.01c	7.07ab
T_3	11.0a	87.08a	25.97a	130	7.54abc	6.83ab
T_4	10.2a	83.43a	25.14a	140	7.11bc	6.51b
T_5	11.1a	84.67a	25.41a	137	7.03c	7.08ab
T_6	10.8a	87.34a	25.26a	138	7.18a	7.38a
T_7	10.7a	87.77a	25.42a	138	8.00a	7.40a
SE (±)	0.46	1.52	0.32	4.68	0.19	0.21

In a column figures having similar letter(s) do not differ significantly whereas figures with dissimilar letter(s) differ significantly as per DMRT at 5% level of significance.

4.1.3 Combined effects of irrigation and fertilizer on the growth and yield of Boro rice

The combined effects of different doses of fertilizer and irrigation on the yield parameters and yield of Boro rice were not significantly different (Table 4.2). The highest number of effective tiller per hill of rice (11.3) was recorded with the treatment combination I_1T_6 (continuous flooded + 50% NPKSZn + 3.5 ton compost/ha) & I_2T_3 (Saturated condition + 70% NPKSZn + 3 ton cowdung ha^{-1}) which was almost similar to I_1T_5, I_1T_7 and I_2T_5 treatment combinations and the lowest number of effective tiller of rice (7.6) was found in I_2T_0 (saturated condition + control treatment) treatment combination (Figure 4).

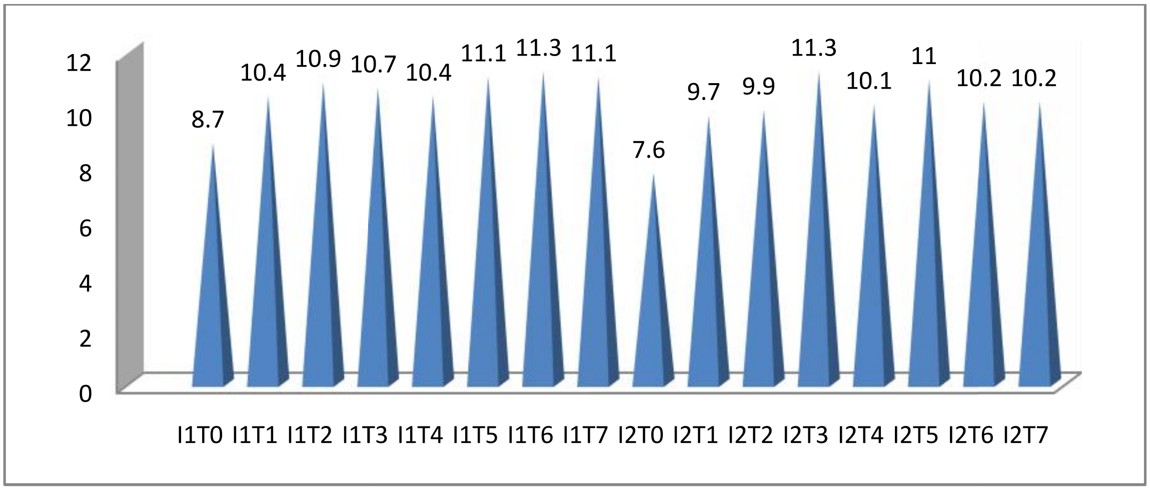


Figure 4: Effect of irrigation and fertilizer on the number of effective tiller per hills

The highest number of plant height was (90.15 cm) recorded with the treatment combination I_2T_6 (Saturated condition + 50% NPKSZn + 3.5 ton poultry manure ha^{-1}) which was similar to I_1T_7 and I_2T_7 treatment combinations and the lowest number of plant height was 72.16 cm found in I_1T_0 (Continuous flooding + Control) treatment combination (Figure 5).

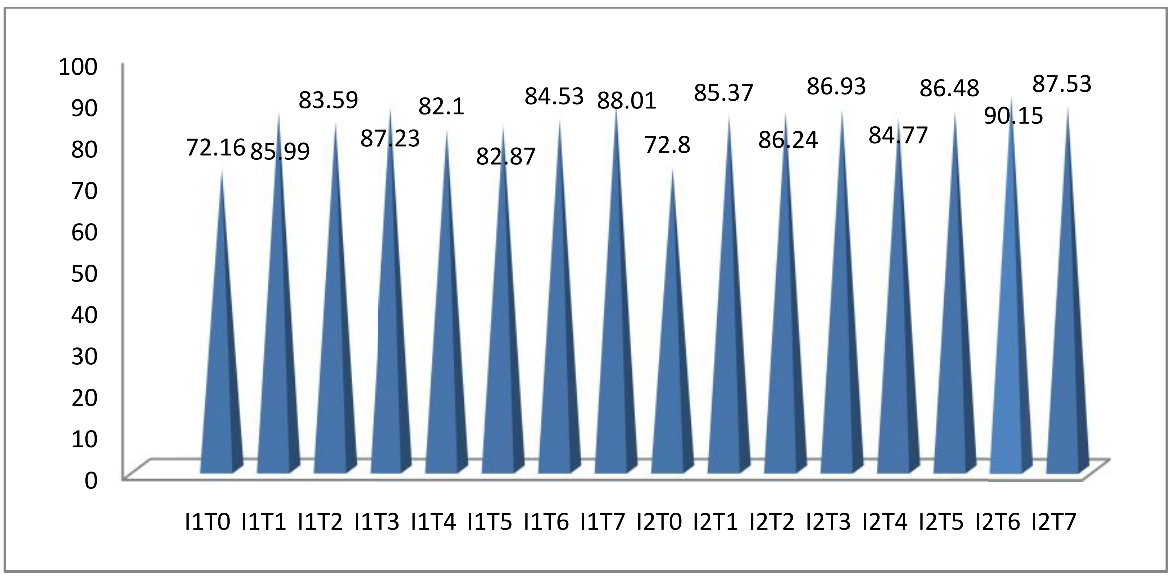


Figure 5: Effect of irrigation and fertilizer on the plant height (cm)

The highest number of panicle length was (26.14 cm) recorded with the treatment combination I_2T_3 (Saturated condition + 70% NPKSZn + 3 ton cowdung ha^{-1}) which was similar to I_2T_6 and

I_2T_7 treatment combinations and the lowest number of panicle length was 22.23 cm found in I_1T_0 (Continuous flooding + Control) treatment combination (Figure 6).

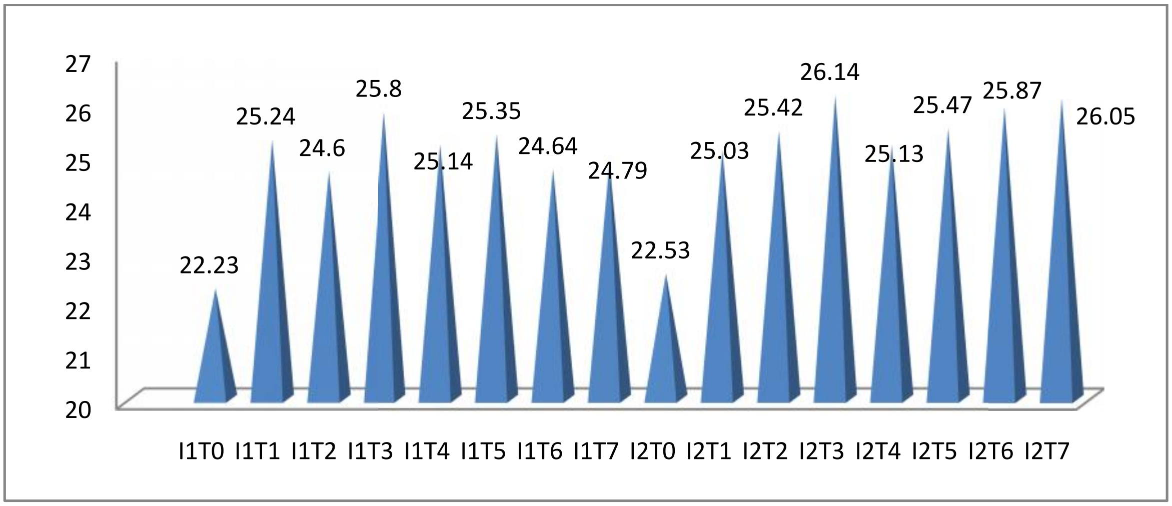


Figure 6: Effect of irrigation and fertilizer on the panicle length (cm)

The highest number of filled grains per panicle was (149) recorded with the treatment combination I_2T_7 (Saturated condition + 70% NPKSZn + 2.1 ton poultry manure ha^{-1}) which was similar to I_1T_1, I_1T_2, I_1T_4, I_2T_1 and I_2T_6 treatment combinations and the lowest number of filled grain per panicle was 102 found in I_2T_0 (Saturated condition + Control) treatment combination (Figure 7).

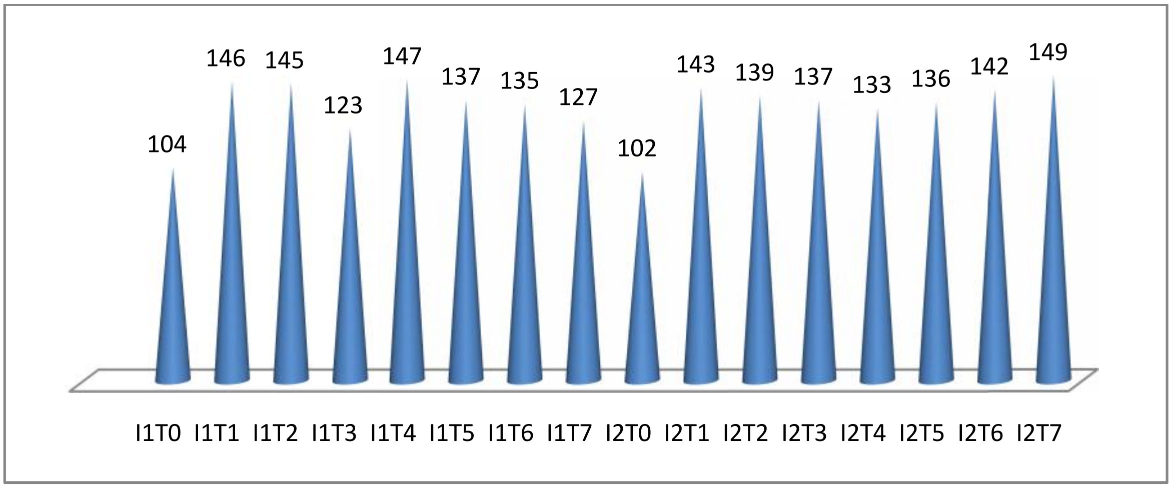


Figure 7: Effect of irrigation and fertilizer on the number of filled grain/panicle

The highest number of 1000 seed weight was (22.5 gm) recorded with the treatment combination I_2T_3 (Saturated condition + 70% NPKSZn + 3 ton cowdung ha^{-1}) which was similar to I_1T_2 and I_1T_4 treatment combinations and the lowest number of 1000 seed weight was 20.33 gm found in I_2T_0 (Saturated condition + Control) treatment combination (Figure 8).

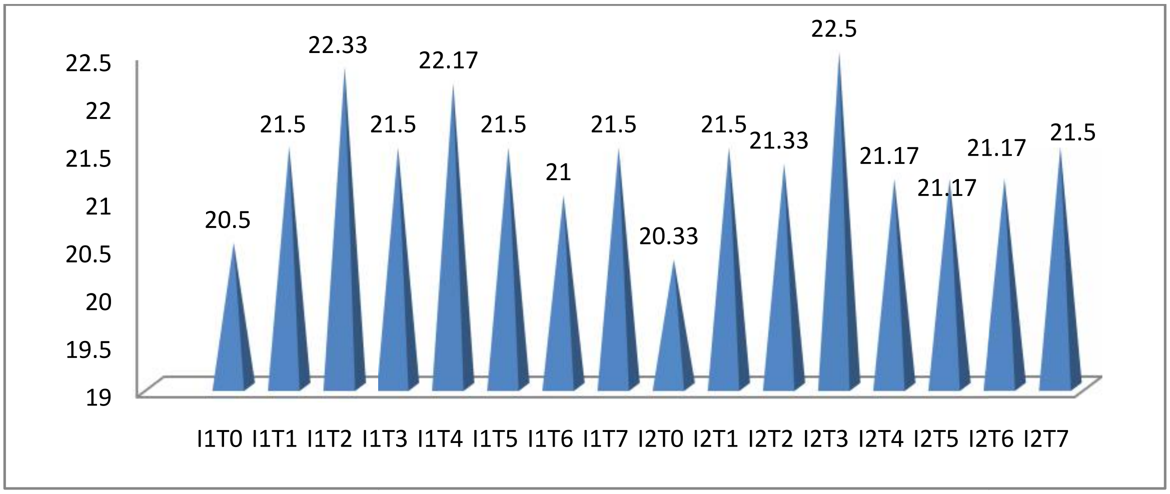


Figure 8: Effect of irrigation and fertilizer on the 1000 seed weight (g)

The highest straw yield of rice was (8.26 ton/ha) recorded with the treatment combination I_1T_6 (continuous flooded + 50% NPKSZn + 3.5 ton compost/ha) which was similar to I_1T_1, I_1T_7, I_2T_6 and I_2T_7 treatment combinations and the lowest straw yield was 4.21 ton/ha found in I_2T_0 (saturated condition + control treatment) treatment combination (Figure 9).

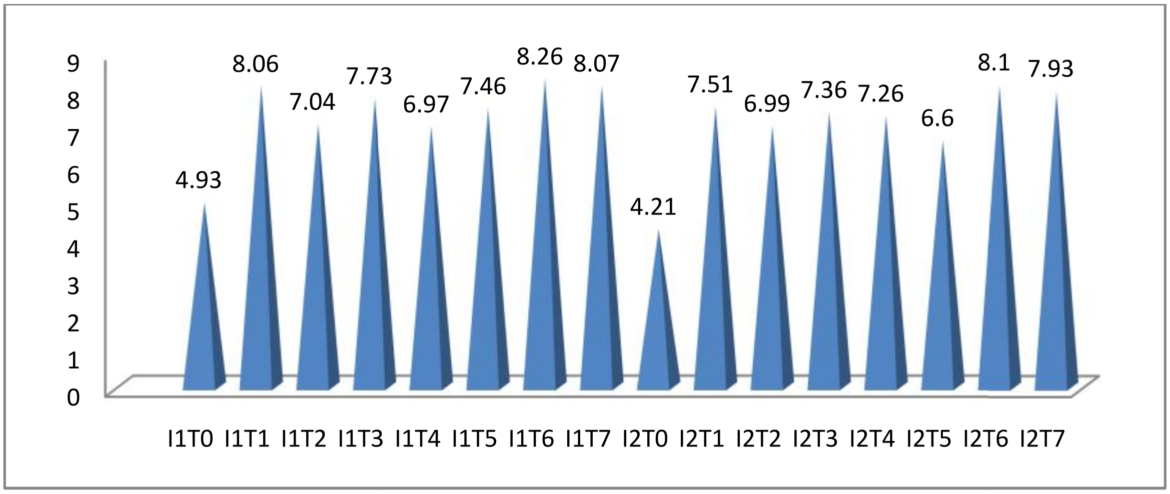


Figure 9: Effect of irrigation and fertilizer on the straw yield (ton/ha)

The highest grain yield of rice was (7.51 ton/ha) recorded with the treatment combination I_1T_1 (continuous flooded condition + 100% recommended dose of fertilizer) which was closely similar to I_1T_5, I_1T_6, I_1T_7, I_2T_6, I_2T_7 treatment combinations and the lowest grain yield was 3.69 ton/ha found in I_2T_0 (saturated condition + control treatment) treatment combination (Figure 10).

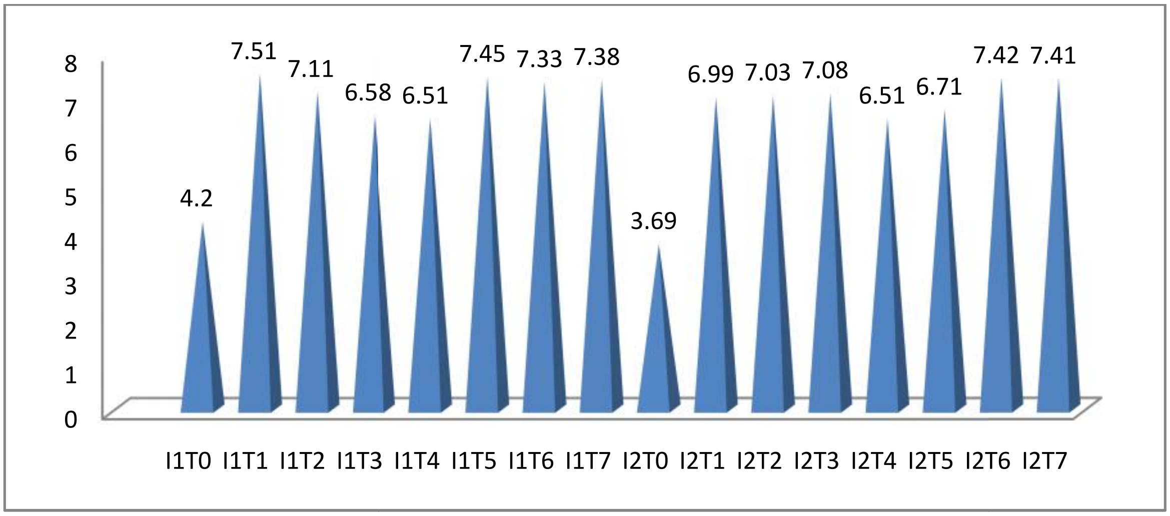


Figure 10: Effect of irrigation and fertilizer on the grain yield (ton/ha)

Table 4.2: Interaction effect of fertilizer and irrigation on the growth and yield of Boro rice

Treatments	Number of effective tiller	Plant height (cm)	Panicle length(cm)	Number of Filled grain/panicle	1000 seed weight (g)	Straw yield (t/ha)	Grain yield (t/ha)
I_1T_0	8.7	72.16	22.23	104	20.50	4.93	4.20
I_1T_1	10.4	85.99	25.24	146	21.50	8.06	7.51
I_1T_2	10.9	83.59	24.60	145	22.33	7.04	7.11
I_1T_3	10.7	87.23	25.80	123	21.50	7.73	6.58
I_1T_4	10.4	82.10	25.14	147	22.17	6.97	6.51
I_1T_5	11.1	82.87	25.35	137	21.50	7.46	7.45
I_1T_6	11.3	84.53	24.64	135	21.00	8.26	7.33
I_1T_7	11.1	88.01	24.79	127	21.50	8.07	7.38
I_2T_0	7.6	72.80	22.53	102	20.33	4.21	3.69
I_2T_1	9.7	85.37	25.03	143	21.50	7.51	6.99
I_2T_2	9.9	86.24	25.42	139	21.33	6.99	7.03
I_2T_3	11.3	86.93	26.14	137	22.50	7.36	7.08
I_2T_4	10.1	84.77	25.13	133	21.17	7.26	6.51
I_2T_5	11.0	86.48	25.47	136	21.17	6.60	6.71
I_2T_6	10.2	90.15	25.87	142	21.17	8.10	7.42

I_2T_7	10.2	87.53	26.05	149	21.50	7.93	7.41
SE (±)	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**

In a column figures having similar letter(s) do not differ significantly whereas figures with dissimilar letter(s) differ significantly as per DMRT at 5% level of significance.

4.1.4 Effect of irrigation on the N and P concentration of pore-water during boro rice growing period

The pore-water N, P, K and S concentrations were influenced by different irrigation management in the boro rice field. The pore-water N concentration was not significantly influenced by different levels of irrigation but higher pore-water N concentration was found in continuous flooded condition and lower in saturated condition. The higher levels of pore-water N concentrations were found inside the core where crop was not grown. There was no significant influence of irrigation on the pore-water P concentrations and higher levels of pore-water P were found in the saturated condition of rhizospheric zone of rice plant compared to continuous flooded condition.

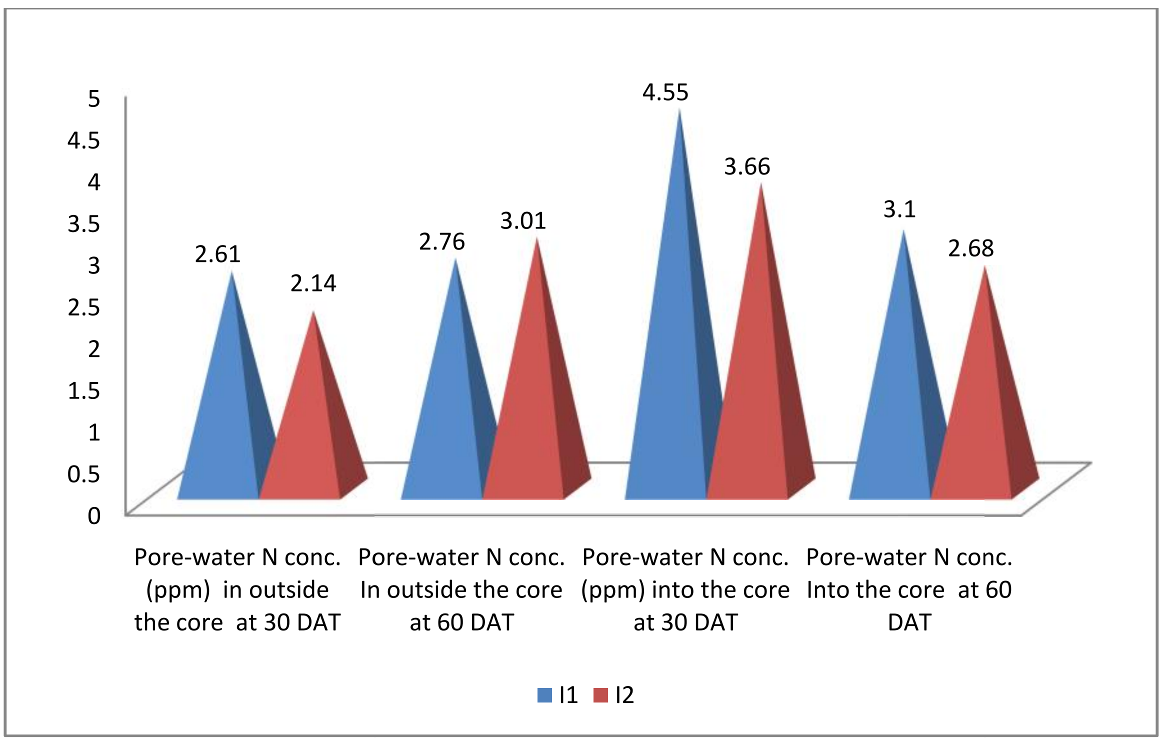


Figure 11: Effect of Irrigation on the N Concentrations of Pore-Water during Boro Rice Growing Period

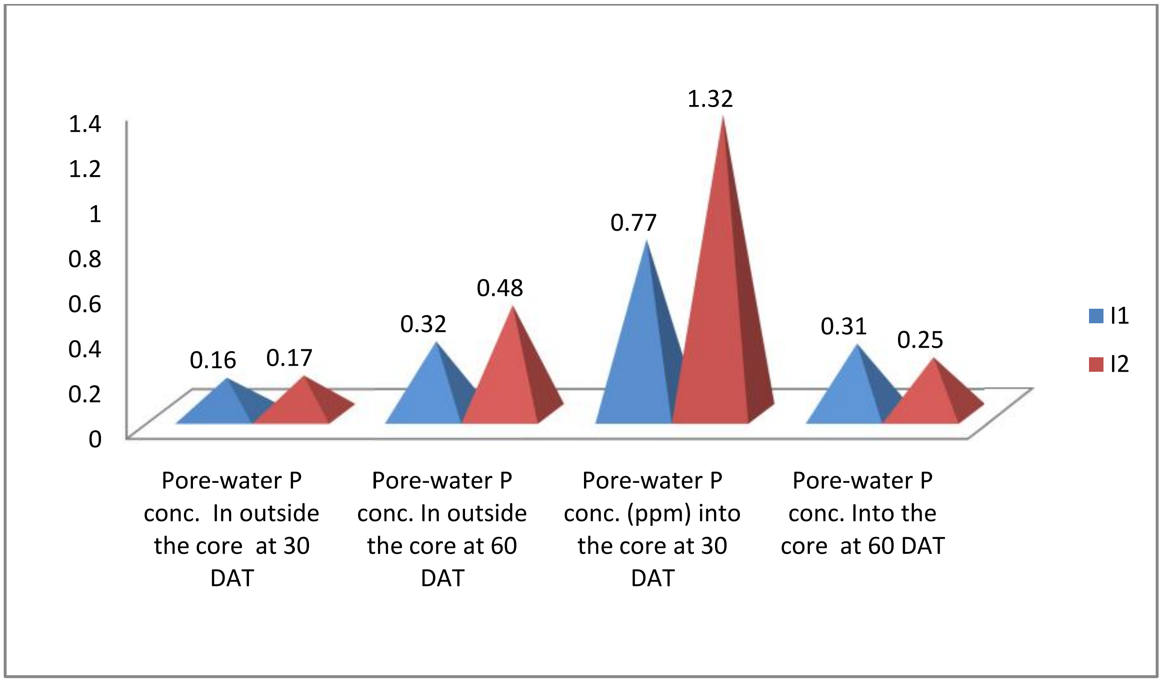


Figure 12: Effect of Irrigation on the P Concentrations of Pore-Water during Boro Rice Growing Period

4.1.5 Effects of fertilizer and manure on the pore-water N and P concentrations

The pore-water N, P, K and S concentrations were influenced by the application of different fertilizer treatments. The pore-water N, P, K and S concentrations in the cropped zone (outside the ring) were different from inside the core where root zone was absent (Table 4.3). The higher levels of pore-water N concentrations were found in without cropped area (inside the core) compared to cropped area (outside the core) at 30 DAT. The pore-water N concentrations significantly increased in the treatments where fertilizer and manure were applied. Among the fertilizer treatments, the pore-water N concentration at 30 DAT varied from 1.50 ppm to 2.85 ppm in cropped area (outside the core) and the range of pore-water N concentration varied from 2.68 – 5.78 ppm into the core. At 30 DAT the highest level of available N (2.85 ppm in cropped area) concentration was obtained from T_7 treatment where 70% NPKSZn + 2.1 ton poultry manure/ha was used which was statistically similar to T_1, T_2 (100% recommended dose of fertilizer) and T_6 (70% NPKSZn + 3 ton compost/ha) treatments. Similarly, at 60 DAT the highest level of available N (4.29 ppm in cropped area) concentration was obtained from T_2 treatment where 50% NPKSZn + 5 ton cowdung/ha was used which was almost similar to T_7 treatment. The pore water N concentrations were reduced into the core due to leaching.

Table 4.3: Effect of fertilizer and manure on the pore-water N concentration of 30 And 60 DAT

Treatments	Pore-water N conc. (ppm) in outside the core at 30 DAT	Pore-water N conc. (ppm) in outside the core at 60 DAT	Pore-water N conc. (ppm) inside the core at 30 DAT	Pore-water N conc. (ppm) inside the core at 60 DAT
T_0	1.50c	1.56	2.68b	2.03
T_1	2.65ab	2.53	5.78a	3.75
T_2	2.78ab	4.29	3.28b	3.22
T_3	1.91bc	2.80	3.85b	2.35
T_4	2.35abc	2.98	4.08ab	2.95
T_5	2.43ab	2.65	4.09ab	2.64
T_6	2.53ab	2.80	3.85b	2.50
T_7	2.85a	3.55	4.27ab	3.65
SE (±)	**0.26**	**0.38**	**0.49**	**0.26**

In a column figures having similar letter(s) do not differ significantly whereas figures with dissimilar letter(s) differ significantly as per DMRT at 5% level of significance.

The levels of pore-water P concentrations were significantly influenced by manure and fertilizer application (Table 4.4). The higher pore-water P concentrations were found into the core and lower in the outside of the cores at 30 DAT and similar pore-water P concentrations were found in the pore-water of inside and outside the core at 60 DAT. Among the fertilizer treatments, the higher pore-water P concentrations were recorded in T_6 and T_7 treatments where NPKS and poultry manure were used which was similar to T_1 and T_3 treatments. The lowest pore-water P concentration was found in the control treatment where fertilizer was not used.

Table 4.4: Effect of fertilizer and manure on the pore-water P concentration of 30 and 60 DAT

Treatments	Pore-water P conc. (ppm) in outside the core at 30 DAT	Pore-water P conc. (ppm) in outside the core at 60 DAT	Pore-water P conc. (ppm) inside the core at 30 DAT	Pore-water P conc. (ppm) inside the core at 60 DAT
T_0	0.11c	0.30c	0.33d	0.08c
T_1	0.15bc	0.38abc	1.81a	0.17c
T_2	0.15bc	0.43ab	0.66cd	0.17c
T_3	0.20a	0.38abc	1.36ab	0.40b

T_4	0.14bc	0.34bc	1.34ab	0.14c
T_5	0.15bc	0.41abc	0.65cd	0.16c
T_6	0.18ab	0.50a	1.14bc	0.62a
T_7	0.22a	0.45ab	1.12bc	0.49b
SE (±)	**0.013**	**0.04**	**0.19**	**0.034**

In a column figures having similar letter(s) do not differ significantly whereas figures with dissimilar letter(s) differ significantly as per DMRT at 5% level of significance.

4.1.6. Combined effects of irrigation and fertilizer on the pore-water N and P concentration

The combined effects of different doses of fertilizer and irrigation on the pore-water N and P concentrations were significantly different (Table 4.5). The higher pore-water N concentrations were found into the core and outside the core at 30DAT than 60DAT. At 30 DAT, the highest available N concentration was recorded with the treatment combination I_1T_1 (Continuous flooding + 100% NPKSZn) which were statistically similar to I_2T_5 and I_2T_7 treatment combinations. At 60 DAT, the pore-water N concentration of root-zone area was not significantly affected by combined application of irrigation and fertilizer but higher concentrations of N were found in the I_1T_2, I_2T_2 and I_2T_7 treatment combinations. The N concentrations of the pore-water samples of organic plus inorganic treatments (into the core) of 30 and 60 DAT were higher where 70% NPKS + organic fertilizer were applied. The higher levels of pore-water P concentrations were found in the pore-water samples of rice cropped area and non-cropped area where I_2T_6, I_2T_7 and I_1T_7 treatment combinations were applied.

Table 4.5: Interaction effect of fertilizer and irrigation on the pore-water N concentration

Treatments	Pore-water N conc. (ppm) in outside the core at 30 DAT	Pore-water N conc. (ppm) outside the core at 60 DAT	Pore-water N conc. (ppm) inside the core at 30 DAT	Pore-water N conc. (ppm) inside the core at 60 DAT
I_1T_0	2.25bcde	1.42	3.55abcd	2.10def
I_1T_1	4.50a	1.90	6.30a	4.50a
I_1T_2	2.40bcd	4.39	4.45abcd	3.99ab
I_1T_3	2.80bcd	2.45	3.50bcd	2.95bcde
I_1T_4	1.90cdef	2.80	5.80ab	2.45cdef

I_1T_5	1.55def	3.20	3.28cd	3.18abcd
I_1T_6	3.10bc	2.45	4.20abcd	1.40f
I_1T_7	2.40ef	3.45	4.34abcd	4.20ab
I_2T_0	0.75f	1.70	2.80cd	1.95def
I_2T_1	0.80f	3.15	5.25abc	3.00bcde
I_2T_2	3.15bc	4.20	2.10d	2.45cdef
I_2T_3	1.03ef	3.15	4.20abcd	1.75ef
I_2T_4	2.80bcd	3.15	2.35d	3.45abc
I_2T_5	3.30ab	2.10	4.90abc	2.10def
I_2T_6	1.95cdef	3.15	3.50bcd	3.60abc
I_2T_7	3.30ab	3.65	4.20abcd	3.10bcd
SE (±)	**0.37**	**NS**	**0.49**	**0.37**

In a column figures having similar letter(s) do not differ significantly whereas figures with dissimilar letter(s) differ significantly as per DMRT at 5% level of significance.

Table 4.6: Interaction effect of fertilizer and irrigation on the pore-water P concentration

Treatments	Pore-water P conc. (ppm) outside the core at 30 DAT	Pore-water P conc. (ppm) outside the core at 60 DAT	Pore-water P conc. (ppm) inside the core at 30 DAT	Pore-water P conc. (ppm) inside the core at 60 DAT
I_1T_0	0.11d	0.22f	0.20e	0.07d
I_1T_1	0.16bcd	0.40bcde	0.25e	0.20cd
I_1T_2	0.16bcd	0.44bcd	0.59cde	0.23cd
I_1T_3	0.15cd	0.31def	0.96bcde	0.44b
I_1T_4	0.14cd	0.28def	1.21bcd	0.14d
I_1T_5	0.16bcd	0.32def	0.82bcde	0.15d
I_1T_6	0.13d	0.25ef	0.83bcde	0.78a
I_1T_7	0.24a	0.32def	1.35bcd	0.49b
I_2T_0	0.11d	0.37cdef	0.45de	0.10d
I_2T_1	0.14cd	0.36cdef	3.37a	0.14d
I_2T_2	0.13d	0.42bcde	0.73cde	0.12d
I_2T_3	0.25a	0.45bcd	1.76b	0.35bc
I_2T_4	0.15cd	0.40bcde	1.48bc	0.14d

I_2T_5	0.15cd	0.51bc	0.47de	0.18cd
I_2T_6	0.22ab	0.75a	1.44bc	0.46b
I_2T_7	0.20abc	0.57b	0.88bcde	0.49b
SE (±)	**0.018**	**0.035**	**0.26**	**0.05**

In a column figures having similar letter(s) do not differ significantly whereas figures with dissimilar letter(s) differ significantly as per DMRT at 5% level of significance.

4.1.7 Effect of irrigation on the K and S concentration of pore-water

The pore-water K and S concentrations were influenced by different irrigation management in the Boro rice field. The pore-water K concentration was not significantly influenced by different levels of irrigation but higher pore-water K concentration was found in continuous flooded condition and lower in saturated condition. The higher levels of pore-water K concentrations were found inside the core where crop was not grown (Table 4.7). Almost similar levels of pore-water S concentrations were found in the cropped and without rice cultivated soil (Table 4.8).

Table 4.7: Effect of irrigation on the in pore-water K concentrations

Treatments	**Pore-water K conc. (ppm) In outside the core at 30 DAT**	**Pore-water K conc. (ppm) in outside the core at 60 DAT**	**Pore-water K conc. (ppm) inside the core at 30 DAT**	**Pore-water K conc. (ppm) inside the core at 60 DAT**
I_1	0.75	3.47	2.85a	3.47
I_2	0.74	2.87	1.48b	2.87
SE (±)	NS	NS	0.21	NS

In a column figures having similar letter(s) do not differ significantly whereas figures with dissimilar letter(s) differ significantly as per DMRT at 5% level of significance.

Table 4.8: Effect of irrigation on the in pore-water S concentrations

Treatments	Pore-water S conc. (ppm) in outside the core at 30 DAT	Pore-water S conc. (ppm) in outside the core at 60 DAT	Pore-water S conc. (ppm) inside the core at 30 DAT	Pore-water S conc. (ppm) inside the core at 60 DAT
I_1	2.60	2.86a	3.49	2.45a
I_2	2.19	1.91b	3.45	2.81b
SE (±)	NS	0.03	NS	0.06

In a column figures having similar letter(s) do not differ significantly whereas figures with dissimilar letter(s) differ significantly as per DMRT at 5% level of significance.

4.1.8 Effects of fertilizer and manure on the pore-water K and S concentrations

The pore-water K and S concentrations were influenced by the application of different fertilizer treatments. The pore-water K and S concentrations in the cropped zone (outside the ring) were different from inside the core where root zone was absent. The higher levels of pore-water K concentrations were found in without cropped area (inside the core) compared to cropped area (outside the core) at 30 and 60 DAT. The higher levels of pore-water K concentrations were found in the treatments where fertilizer and manure were applied. Among the fertilizer treatments, the K concentration (outside the core) at 60 DAT varied from 2.16 ppm to 4.64 ppm and the range of pore-water K concentration inside the core varied from 2.48 – 5.58 ppm. The highest level of available K (4.64 ppm) in cropped area and (5.58 ppm) uncropped area were obtained from T_6 and T_7 (70% NPKSZn + 2.1 ton poultry manure/ha) treatments, respectively. The pore-water K concentrations decreased in the cropped area may be due to higher accumulation of K by rice plants. At 30 DAT, the highest K concentration was recorded in T_2 treatment which was statistically similar to T_6 and T_7 treatments. The lowest pore-water K concentrations were found in the control treatment where fertilizer was not used (Table 4.9). The similar concentrations of pore-water S were found in the root zone area (outside the core) and without cropped area (inside the core) (Table 4.10). The application of fertilizer and manure influenced the pore-water S concentration of root-zone area and the highest level of S (3.58 ppm) was found in T_7 treatment at 60 DAT.

Table 4.9: Effect of fertilizer and manure on the pore-water K concentration of 30 and 60 DAT

Treatments	Pore-water K conc. (ppm) in outside the core at 30 DAT	Pore-water K conc. (ppm) in outside the core at 60 DAT	Pore-water K conc. (ppm) inside the core at 30 DAT	Pore-water K conc. (ppm) inside the core at 60 DAT
T_0	0.33c	2.16c	0.54e	2.48d
T_1	0.54bc	2.45c	1.69d	4.89ab
T_2	1.26a	3.14bc	1.75d	3.78bc
T_3	0.85abc	3.72ab	2.37c	4.31bc
T_4	0.68bc	2.93bc	2.17cd	3.62c
T_5	0.51bc	3.25bc	1.76d	4.10bc
T_6	0.79abc	4.64a	3.15b	5.53a
T_7	0.98ab	3.05bc	3.91a	5.58a
SE (±)	**0.13**	**0.31**	**0.15**	**0.33**

In a column figures having similar letter(s) do not differ significantly whereas figures with dissimilar letter(s) differ significantly as per DMRT at 5% level of significance.

Table 4.10: Effect of fertilizer and manure on the pore-water S concentration of 30 and 60 DAT

Treatments	Pore-water S conc. (ppm) in	Pore-water S conc. (ppm) in	Pore-water S conc. (ppm)	Pore-water S conc. (ppm)

	outside the core at 30 DAT	**outside the core at 60 DAT**	**inside the core at 30 DAT**	**inside the core at 60 DAT**
T_0	1.47	1.43c	1.95d	1.42c
T_1	2.23	2.37bc	4.19ab	3.33a
T_2	2.45	2.26bc	2.51d	2.40ab
T_3	2.88	2.77ab	4.28a	2.95ab
T_4	2.69	3.02ab	3.53c	2.57ab
T_5	2.46	2.07bc	3.48c	2.27bc
T_6	3.03	1.56c	4.27a	2.83ab
T_7	1.97	3.58a	3.57bc	3.26a
SE (±)	**NS**	**0.27**	**0.19**	**0.27**

In a column figures having similar letter(s) do not differ significantly whereas figures with dissimilar letter(s) differ significantly as per DMRT at 5% level of significance.

4.1.9 Combined effects of irrigation and fertilizer on the pore-water K and S concentrations

The pore-water K and S concentrations were significantly different due to combined application of different levels of fertilizer and irrigation. The higher pore-water K concentrations were found in the samples of inside the core compared to outside the core (Table 4.11). At 30 DAT, the highest pore-water K concentration of outside the core (1.86 ppm) was found in I_1T_2 (Continuous flooding + 50% NPKS + 5 ton cowdung ha^{-1}) treatment combination. At 60 DAT, the highest pore-water K concentration of outside the core (4.71 ppm) was found in I_2T_6 (Saturated condition + 50% NPKSZn + 3.5 ton poultry manure ha^{-1}) treatment combination. At 30 DAT, the highest pore-water K concentration of inside the core (5.26 ppm) was recorded with the treatment combination I_1T_7 (Continuous flooding + 70% NPKSZn + 2.1 ton poultry manure ha^{-1}) which were statistically similar to I_1T_6 treatment combinations. At 30 DAT, the highest pore-water S concentration of outside the core (4.50 ppm) was found in I_1T_6 (Continuous flooding + 50% NPKSZn + 3.5 ton poultry manure ha^{-1}) treatment combination. The pore-water of 60 DAT of S (Table 4.12), outside the core (cropped area) was significantly affected by the interaction effects of irrigation and fertilizer and highest concentration of 4.58 ppm was obtained from I_1T_4 (Continuous flooding + 50% NPKSZn + 5 ton compost ha^{-1}) treatment which was statistically similar with I_1T_3 and I_1T_7 and I_2T_7 treatments combinations. At 30 DAT, the highest pore-water S concentration of inside the core (5.60 ppm) was found in I_2T_1 (Saturated condition + 100% ($N_{120}P_{25}K_{60}S_{20}Zn_2$) Recommended dose) treatment combination. At 60 DAT, the highest pore-water S (3.81 ppm) concentration in the samples of outside the core was recorded with the treatment combination I_2T_7 (Saturated condition + 70% NPKSZn + 2.1 ton poultry manure ha^{-1}).

Table 4.11: Interaction effect of fertilizer and irrigation on the pore-water K concentration

Treatments	Pore-water K conc. (ppm) in outside the core at 30 DAT	Pore-water K conc. (ppm) outside the core at 60 DAT	Pore-water K conc. (ppm) inside the core at 30 DAT	Pore-water K conc. (ppm) inside the core at 60 DAT
I_1T_0	0.36c	1.98e	0.68hi	2.09
I_1T_1	0.64bc	2.34de	1.89cdef	5.00
I_1T_2	1.86a	3.83abcd	2.69b	4.36
I_1T_3	1.04bc	4.68a	2.84b	4.26
I_1T_4	0.34c	3.09bcde	2.55bcd	3.62
I_1T_5	0.34c	4.15abc	2.31bcde	4.36
I_1T_6	0.64bc	4.57ab	4.60a	6.38
I_1T_7	0.78bc	3.09bcde	5.26a	6.38
I_2T_0	0.28c	2.34de	0.41i	2.87
I_2T_1	0.45bc	2.55de	1.49fg	4.78
I_2T_2	0.68bc	2.45de	0.81ghi	3.19
I_2T_3	0.68bc	2.77cde	1.89cdef	4.36
I_2T_4	1.01bc	2.76cde	1.79def	3.62
I_2T_5	0.68bc	2.34de	1.22fgh	3.83
I_2T_6	0.95bc	4.71a	1.70ef	4.68

I_2T_7	1.19ab	3.02bcde	2.57bc	5.32
SE (±)	**0.18**	**0.44**	**0.21**	**NS**

In a column figures having similar letter(s) do not differ significantly whereas figures with dissimilar letter(s) differ significantly as per DMRT at 5% level of significance.

Table 4.12: Interaction effect of fertilizer and irrigation on the pore-water S concentration

Treatments	Pore-water S conc. (ppm) outside the core at 30 DAT	Pore-water S conc. (ppm) outside the core at 60 DAT	Pore-water S conc. (ppm) inside the core at 30 DAT	Pore-water S conc. (ppm) Inside the core at 60 DAT
I_1T_0	1.56	1.85efgh	1.36i	1.43
I_1T_1	2.00	2.80bcdef	2.79fgh	2.90
I_1T_2	3.02	1.66efgh	2.84efgh	2.16
I_1T_3	2.44	3.29abcd	4.33bc	2.89
I_1T_4	1.94	4.58a	3.76cde	2.91
I_1T_5	2.56	2.68bcdef	3.68cdef	2.06
I_1T_6	4.50	2.37bcdefg	4.86ab	2.47
I_1T_7	2.75	3.47ab	4.30bc	2.71
I_2T_0	1.38	1.02gh	2.54gh	1.41
I_2T_1	2.45	1.94defgh	5.60a	3.72
I_2T_2	1.87	2.86bcde	2.17hi	2.64
I_2T_3	3.31	2.25cdefg	4.23bcd	3.02
I_2T_4	3.44	1.46fgh	3.29defg	2.25
I_2T_5	2.35	1.47fgh	3.29defg	2.49
I_2T_6	1.56	0.76h	3.68cdef	3.18
I_2T_7	1.19	3.50abc	2.83efgh	3.81

SE (±)	**0.53**	**0.38**	**0.27**	**0.38**

In a column figures having similar letter(s) do not differ significantly whereas figures with dissimilar letter(s) differ significantly as per DMRT at 5% level of significance.

4.1.10 Effect of irrigation and fertilizer on N, P, K and S concentration in Boro rice grain and straw

Insignificant variation was observed in N, P, K and S concentration in grain and straw of boro rice when the field was irrigated with two different irrigations. The grain and straw N and S concentrations were significantly influenced by fertilizer and manure treatments. The highest grain N concentration (1.31%) was found in T_5 treatment which was closely similar to T_1, T_2, T_3 and T_7 treatments. Similarly the highest P concentration (0.272%) in T_3 treatment and S concentration (0.091%) was found in T_2 treatment where organic plus inorganic fertilizers were used (Table 4.13).

The highest straw N concentration (0.730%) was recorded in T_1, straw P concentration (0.140%) was recorded in T_2 (50% NPKSZn + 5 ton cowdung/ha), K(1.63%) in T_3 and highest S(0.052%) concentration was recorded in T_6 (50% NPKSZn + 3.5 ton poultry manure/ha) treatment and in all cases the lowest concentration was found from T_0 treatment (Table 4.14). Higher levels of N, P, K and S were accumulated in combined application of organic plus inorganic fertilizer. The grain N, P, K, S and straw P, K, S concentrations were not influenced by interaction effect of irrigation and fertilizer. The straw N concentration was significantly influenced by interaction effect of irrigation and fertilizer. Similarly the highest straw N concentration (0.64%) was obtained from T_3 70% (NPKSZn + 3 ton cowdung ha^{-1}) treatment.

Table 4.13: Effect of fertilizer and manure on NPKS concentration of Boro rice grain

Treatment	Concentration (%) in grain			
	N	P	K	S
T_0	1.16bc	0.229	0.167	0.065cd
T_1	1.28a	0.235	0.195	0.086b
T_2	1.27ab	0.239	0.195	0.091a
T_3	1.29a	0.272	0.167	0.087ab
T_4	1.13c	0.230	0.195	0.063d
T_5	1.31a	0.210	0.195	0.087ab
T_6	1.16bc	0.239	0.167	0.087ab
T_7	1.28a	0.204	0.195	0.067c
SE (±)	0.034	NS	NS	0.006

In a column figures having similar letter(s) do not differ significantly whereas figures with dissimilar letter(s) differ significantly as per DMRT at 5% level of significance.

Table 4.14: Effect of fertilizer and manure on NPKS concentration of Boro rice straw

Treatment	Concentration (%) in straw			
	N	P	K	S
T_0	0.530bc	0.049	1.31	0.035de
T_1	0.627ab	0.053	1.50	0.038cd
T_2	0.730a	0.057	1.46	0.044b
T_3	0.640ab	0.048	1.63	0.031e
T_4	0.467c	0.053	1.61	0.051a
T_5	0.553bc	0.054	1.59	0.037d

T_6	0.510c	0.055	1.39	0.052a
T_7	0.543bc	0.053	1.46	0.041b
SE (±)	0.031	NS	NS	0.004

In a column figures having similar letter(s) do not differ significantly whereas figures with dissimilar letter(s) differ significantly as per DMRT at 5% level of significance.

CHAPTER V

SUMMARY AND CONCLUSION

The experiment was conducted in the Farm of Sher-e-Bangla Agricultural University, Dhaka, Bangladesh during the period from December 2012 to July 2013 to study the effect of fertilizer, manure and irrigation on the yield and nutritional accumulation in rice. BRRI dhan 29 was used as the test crop in this experiment. The experiment consists of 2 factors i.e. irrigation and fertilizer plus manure. Two levels of irrigations (I_1 = Continuous flooding and I_2 = Saturated condition) were used with 8 levels of fertilizer plus manure, as T_0: Control, T_1: 100% ($N_{120}P_{25}K_{60}S_{20}Zn_2$) Recommended dose of Fertilizer, T_2: 50% NPKSZn + 5 ton cow-dung ha^{-1}, T_3: 70% NPKSZn + 3 ton cowdung ha^{-1}, T_4: 50% NPKSZn + 5 ton compost ha^{-1}, T_5: 70% NPKSZn + 3 ton compost ha^{-1}, T_6: 50% NPKSZn + 3.5 ton poultry manure ha^{-1} and T_7: 7070% NPKSZn + 2.1 ton poultry manure ha^{-1}, with 16 treatment combination as I_1T_0 = (Continuous flooding + Control), I_1T_1 = Continuous flooding + 100% ($N_{120}P_{25}K_{60}S_{20}Zn_2$) (Recommended dose), I_1T_2 = (Continuous flooding + 50% NPKSZn + 5 ton cow-dung ha^{-1}), I_1T_3 = (Continuous flooding + 70% NPKSZn + 3 ton cow-dung ha^{-1}), I_1T_4 =(Continuous flooding + 50% NPKSZn + 5 ton compost ha^{-1}), I_1T_5 = (Continuous flooding + 70% NPKSZn + 3 ton compost ha^{-1}), I_1T_6 = (Continuous flooding + 50% NPKSZn + 3.5 ton poultry manure ha^{-1}), I_1T_7 = (Continuous flooding + 70% NPKSZn + 2.1 ton poultry manure ha^{-1}), I_2T_0 = (Saturated condition + Control), I_2T_1 = Saturated condition + 100% ($N_{120}P_{25}K_{60}S_{20}Zn_2$) (Recommended dose), I_2T_2 = (Saturated condition + 50% NPKSZn + 5 ton cow-dung ha^{-1}), I_2T_3 = (Saturated condition + 70% NPKSZn +

3 ton cow-dung ha^{-1}), I_2T_4 = (Saturated condition + 50% NPKSZn + 5 ton compost ha^{-1}), I_2T_5 = (Saturated condition + 70% NPKSZn + 3 ton compost ha^{-1}), I_2T_6 = (Saturated condition + 50% NPKSZn + 3.5 ton poultry manure ha^{-1}), I_2T_7 = (Saturated condition + 70% NPKSZn + 2.1 ton poultry manure ha^{-1}), and 3 replications R_1, R_2 and R_3. The total number effective tillers/hill, plant height, panicle length, number of filled grain/panicle, 1000 grain weight, grain yield and straw yield were not significantly affected by single effect of irrigation. The highest number of effective tillers/hill was 11.3, 1000 seed weight was 22.5 g, straw and grain yield were 8.26 ton/ha & 7.51 ton/ha respectively observed from I_1 (Continuous flooding) treatment compared to I_2 (Saturated condition) treatment.

Yield contributing characters and yields were significantly affected by fertilizer and manure. The highest effective tillers/hill of BRRI dhan on Boro season (11.1), plant height (87.77 cm), panicle length (25.97 cm), highest number of filled grain per panicle (144), straw yield (8.0 ton/ha) and grain yield (7.40 ton/ha) were found from T_5 (70% NPKSZn + 3 ton compost ha^{-1}), T_7 (70% NPKSZn + 2.1 ton poultry manure ha^{-1}), T_3 (70% NPKSZn + 3 ton cowdung ha^{-1}), T_1 (100% ($N_{120}P_{25}K_{60}S_{20}Zn_2$) Recommended dose of Fertilizer), T_7 (70% NPKSZn + 2.1 ton poultry manure ha^{-1}) and T_7 (70% NPKSZn + 2.1 ton poultry manure ha^{-1}) treatments respectively and all cases lowest in T_0 treatment. The grain yield of different fertilizer treatments followed the order of $T_7 > T_6 > T_1 > T_5 > T_2 > T_3 > T_4 > T_0$. The yield parameter and yields were insignificantly influenced by combined application of irrigation and fertilizer. The highest values of effective tillers/hill (11.33), grain yield (7.51 ton/ha) and straw yield (8.26 ton/ha) systematically were recorded from I_1T_6 (continuous flooded + 50% NPKSZn + 3.5 ton compost/ha), I_1T_1 (continuous flooded condition + 100% recommended dose of fertilizer) and I_1T_6 (continuous flooded + 50% NPKSZn + 3.5 ton compost/ha) treatments combination respectively. The highest grain yield (7.51 ton/ha) was found in I_1T_1 (continuous flooded condition + 100% recommended dose of fertilizer) which was similar to the yield of I_1T_5 (7.45 ton/ha), I_1T_7 (7.38 ton/ha), I_2T_6 (7.42 ton/ha) and I_2T_7 (7.41 ton/ha) treatment combination. The lowest values of effective tillers/hill (7.6), 1000 grain weight (20.33 gm), grain yield (3.69 ton/ha) and straw yield (4.21 ton/ha) were observed from I_2T_0 (saturated condition + control treatment) treatment combination. The lowest Plant height (72.16 cm), panicle length (26.14 cm), were observed from I_1T_0 (Continuous flooding + Control) treatment combination.

The N, P, K and S concentrations were studied in the pore-water and the concentrations of N, P, K and S varied with the irrigation, fertilizer, cropped, without cropped areas and time. The higher concentration of pore water N, P and K were found in the T_6 (50% NPKS + 3.5 ton poultry manure ha^{-1}) and T_7 (70% NPKSZn + 2.1 ton poultry manure per hectare) treatments where poultry manure and inorganic fertilizer were used. There was a good correlation between yield Vs Pore-water nutrient concentration and Pore-water nutrient Vs grain nutrient accumulation.

The nutrient concentration in BRRI dhan29 rice plant was significantly affected by application of irrigation. The higher levels of grain N, K and S concentrations were recorded from I_1 (Continuous flooding) and P concentrations were recorded from I_2 (Saturated condition) treatment. The highest concentrations of grain N (1.31%), P (0.272%), K (0.195%), S (0.091%) were recorded from T_5 (70% NPKSZn + 3 ton compost ha^{-1}), T_3 (70% NPKSZn + 3 ton cow-dung ha^{-1}), T_1 (100% Recommended dose of Fertilizer), T_2 (50% NPKSZn + 5 ton cow-dung ha^{-1}), T_4 (50% NPKSZn + 5 ton compost ha^{-1}), T_7 (70% NPKSZn + 2.1 ton poultry manure ha^{-}1) and T_2 (50% NPKSZn + 5 ton cow-dung ha^{-1}) treatment combination respectively. The highest concentrations of straw N (0.730%), P (0.057%), were recorded from T_2 (50% NPKSZn + 5 ton cow-dung ha^{-1}) treatment, K (1.63%) were recorded from T_3 (70% NPKSZn + 3 ton cow-dung ha^{-1}) and S (0.052%) were recorded from T_6 (50% NPKSZn + 3.5 ton poultry manure ha^{-1}) treatment. The combined effect of fertilizer and manure significantly influenced the grain and straw N, P, K and S concentrations and higher levels grain nutrient concentrations were observed in the treatments where fertilizer plus manure more used.

From the above discussion it can be concluded that irrigation had no significant effect on yield and yield contributing characters and continuous flooding is preferable than saturated irrigation. The application of inorganic fertilizer plus manure performed better compared to inorganic fertilizer. The application of 100% ($N_{120}P_{25}K_{60}S_{20}Zn_2$) Recommended dose of Fertilizer and continuous flooding was most favorable for improving yield and yield contributing characters of Boro (BRRI dhan 29) rice.

Before recommend findings of the present study, the following recommendations and suggestions may be made:

1. Such study is needed in different agro-ecological zones (AEZ) of Bangladesh for regional adaptability and other performance.

2. Another combination of NPKSZn and others organic manures with different water management may be included for further study.

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APPENDICES

Appendix-I: Particulars of the Agro-ecological Zone of the Experimental site

Agro-ecological region	**:**	Madhupur Tract (AEZ-28)
Land Type	**:**	Medium high land
General soil type	**:**	Non- Calcareous Dark gray floodplain soil
Soil series	**:**	Tejgaon
Topography	**:**	Up land

Location	:	SAU Farm, Dhaka
Field level	:	Above flood level
Drainage	:	Fairly good
Firmness (consistency)	:	Compact to friable when dry.

Appendix-II: Monthly mean weather

AppendixII. Records of meteorological information (monthly) during the period from December, 2012 to July, 2013

Name of the Months	Average Air temp ^{0}C (^{0}F)		Relative humidity (%)	Rainfall/Precipitation mm (inches)
	Maximum	Minimum		
December, 2012	26.4 (79.5)	14.1 (57.4)	50	12.8 (0.504)
January, 2013	25.4 (77.7)	12.7 (54.8)	46	7.7 (0.303)
Fenruary, 2013	28.1 (82.6)	15.5 (59.9)	37	28.9 (1.138)
March, 2013	32.5 (90.5)	20.4 (68.7)	38	65.8 (2.591)
April, 2013	33.7 (92.7)	23.6 (74.5)	42	156.3 (6.154)
May, 2013	32.9 (91.2)	24.5 (76.1)	59	339.4 (13.362)
June, 2013	32.1 (89.8)	26.1 (79)	72	340.4 (13.402)
July, 2013	31.4 (88.5)	26.2 (79.2)	72	373.1 (14.689)

Source: "Weatherbase: Historical Weather for Dhaka, Bangladesh". Weatherbase.com
"Bangladesh - Dacca" (in Spanish). Centro de Investigaciones Fitosociológicas.
"Average Conditions - Bangladesh - Dhaka". BBC

Appendix-III: Some Commonly Used Abbreviations and Symbols

Abbreviations	Full word
%	Percent
@	At the rate
^{0}C	Degree Celsius
^{0}F	Degree Fahrenheit

AEZ	Agro-Ecological Zone
Agric.	Agriculture
Agril.	Agricultural
Agron.	Agronomy
ANOVA	Analysis of variance
BARI	Bangladesh Agricultural Research Institute
BBS	Bangladesh Bureau of Statistics
BD	Bangladesh
BSMRAU	Bangladesh Sheikh MujiburRahman Agricultural University
CEC	Cation Exchange Capacity
cm	Centi-meter
CV%	Percentage of coefficient of variation
DMRT	Duncan's Multiple Range Test
et al.	and others
etc	et cetera
FAO	Food and Agricultural Organization
g	Gram
hr.	Hours
j.	Journal
kg	Kilogram
Kg/ha	Kiligrams per hectare
LAD	Leaf area diseased
m	Meter
mm	Millimetre

MSE	Mean square of the error
No.	Number
ppm	Parts per million
RCBD	Randomized complete block design
Rep.	Replication
Res.	Research
SAU	Sher-e-Bangla Agricultural University
Sc.	Science
SE	Standard Error
Temp	Temperature
Univ.	University
var.	Variety
Wt.	Weight